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FIRST LINES

Ex q. dono Geo. Innes chirurgi

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PHYSIOLOGY,

BY THE CELEBRATED

BARON ALBERTUS HALLER, M.D. &c.

TRANSLATED FROM THE

CORRECT LATIN EDITION

Printed under the INSPECTION of

WILLIAM CULLEN, M.D.

AND COMPARED WITH THE

EDITION publiſhed by H. A. WRISBERG, M.D.

PROFESSOR at GOTTINGEN.

TO WHICH ARE ADDED,

The valuable INDEX originally compoſed for

Dr CULLEN's EDITION;

AND ALL THE

NOTES and ILLUSTRATIONS of PROF. WRISBERG,

now firſt tranſlated into ENGLISH.

IN TWO VOLUMES.

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BRITISH MUSEUM
30 NOV 67

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ADVERTISEMENT.

THE firſt Edition of this Work was publiſhed in 1747. It was deſigned as a correction and improvement of Boerhaave's Inſtitutions, by adding the new diſcoveries of Morgagni, Winſlow, Albinus, Douglas, &c.

IN 1751, another edition was publiſhed; in which ſome things were treated more fully, and others more briefly, than before. The anatomical deſcriptions, particularly, were here abridged; ſome new phyſiological diſcoveries added; and a great number of typographical errors corrected.

A third edition was publiſhed in 1764. Here the author conformed the order of his ſubjects treated of in his Firſt Lines to thoſe of his larger work, and made the number of books contained in both equal; but did not think proper to abridge his Firſt Lines any farther, leſt they ſhould thus have become leſs fit for the purpoſes of a Text-book.

THE demand for this Work ſoon became ſo great, that an edition was printed at Edinburgh in 1766, under the inſpection of the then Profeſſor of the Inſtitutions of Medicine; who had formed the phyſiological part of his lectures upon a ſimilar plan. The greateſt care was taken to have this Edition as exact and free from typographical errors as poſſible; and it was farther improved by the addition of an

Index, which may be conſidered as an elegant compend of the whole. It was thought proper, however, to retain the erroneous numbers of the paragraphs which had eſcaped in the original editions, for the more eaſy referring from one place to another, and that no confuſion might ariſe from uſing the different editions.

Of the laſt-mentioned valuable Edition the preſent Editor, a few years ago, publiſhed an exact tranſlation, in which all poſſible care had been taken to give the true meaning of the Author, in a plain and eaſy manner: An undertaking to which he was incited by the conſideration, that the tranſlation with which Students had been formerly furniſhed, not only was done from an old edition, exceedingly imperfect in compariſon with the laſt one; but was alſo unneceſſarily extended in the printing to double the ſize of the original, and of courſe proportionably enhanced in the price.

The utility of that undertaking was quickly acknowledged by the favourable reception which it met with, and which has already rendered another impreſſion neceſſary. In preparing this for the preſs, the Editor, ſolicitous to give it every improvement in his power, reſolved to avail himſelf of a new edition of the original recently publiſhed, with Notes and Illuſtrations comprehending the later Diſcoveries, by that eminent phyſiologiſt Profeſſor Wriſberg of Gottingen. Accordingly the following tranſlation has not only been compared with the text of that edition, but all the Notes, about 200 in number, have likewiſe been added. At the ſame time, the former low price has only been increaſed by a very ſmall addition, not at all proportioned to the enlargement of the Work or the expence of the Publiſher.

EDINBURGH,
Feb. 1786.

MED. CHIR. SOC.
ABERDEEN.

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FIRST LINES OF PHYSIOLOGY.

Ex libris

CHAP. I.

Soc. Med. Abred

Of a FIBRE. CELLULAR TEXTURE.

Coll

I. THE human body is compoſed either of fluids or ſolids. Since the fluid parts are of different kinds, we ſhall conſider them afterwards in their moſt proper place; but as the ſolids form the moſt ſimple[1] and true baſis of the body, we ſhall begin with their hiſtory before we enter upon the conſideration of the fluids.

II. The *ſolid* parts of animals and vegetables have this fabric in common, that their elements, or the ſmalleſt parts we can ſee by the fineſt microſcope, are either fibres or an unorganized concrete.

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[1] The firſt elements of all the parts of animal bodies conſiſt of a certain earthy ſubſtance conjoined by a gelatinous matter, and of a little air; from which, by the mediation of the primary fibres, plates and membranes, veſſels and inorganic glue, the chief inſtruments of the body, the bones, muſcles, veſſels, membranes, viſcera, teguments, joints, the whole body, are produced according to the different mixture of the elements, and the various addition of the other parts.

III. A *fibre*, in general, may be conſidered as reſembling a line made of points, having a moderate breadth; or rather as a ſlender cylinder. And that the more conſtant or permanent parts of which it is compoſed are earth, is demonſtrated from calcination, or long continued putrefaction.

IV. Theſe earthy particles poſſeſs connection and power of coheſion, not from themſelves or a mere contact, but from the intermediate glue placed betwixt them. This we know from the experiments mentioned above (IV.); and from the eaſy experiment, by which a burnt hair, whoſe parts yet hang together, recovers a degree of firmneſs when dipped in water or oil. Alſo the remains of ivory or bone ſhavings, whoſe jelly has been extracted, become friable, like bones, which, by long expoſure to the weather, are converted into a true earth very ready to imbibe water. But even bones rendered friable by having their gluten extracted, will recover their hardneſs when the gluten is reſtored. It is this gluten alone which conſtitutes the more ſimple parts of animals (II).

V. That this glue is compoſed of oil combined with water by the vital attrition in animals, again appears from the chemical analyſis of bones and hair; from the jelly of bones, ivory, and horns; and from the nature of our aliments themſelves. Nor is there any kind of glue that could more powerfully join the parts of animals together; as we experience in fiſh-glue, and that of joiners or cabinet-makers, &c.

VI. Earthy particles, then, (III.) adhering longitudinally, and connected by an intervening coheſive glue (V.), compoſe in the firſt place one of the leaſt or moſt ſimple fibres, ſuch as we underſtand rather from reaſon than ſenſe.

VII.

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[a] The tender embryos in their ovula, the ſoft plants ſtill latent between the cotyledons, ſeem to be mere gluten; which, after a greater quantity of each has been added, acquires ſo great ſtrength, that it is able to ſupport the due figure of the parts. Among the polypi and ſwiming animalcula, the intermediate degrees are very evident.

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VII. But the fibres which firſt appear to the ſight, are of two kinds. The firſt kind is lineal; namely, fibres, which have their length conſiderably large in proportion to their breadth; and which, by diſpoſing of the elementary particles in a right line, muſt of courſe lie parallel generally with the contiguous fibres. Examples of ſuch fibres we ſee in the bones, and moſt eaſily in thoſe of a fœtus[3]; and likewiſe in the tendons, ligaments, and muſcles: only, we muſt always remember, that the eye never reaches to the ſmalleſt fibres, but to larger ones made up of the ſmalleſt, and like to them in ſlenderneſs, adjoining in a rectilineal courſe. That theſe are not different from the ſmalleſt fibres, we are perſuaded by the moſt accurate microſcopes of Muyſe and Leewenhoeck; by which the muſcular fibres, divided even to the laſt, appear ſimilar to the larger, till at length they ſeem mere lines.

VIII. The ſecond kind of fibres (VII.) is thoſe in which the breadth is frequently larger than their length. Theſe, when looſely interwoven with each other, are called the *cellular* tunic; though the name *tunic* or *membrane* is on many accounts very improper.

IX. This cellular ſubſtance is made up of an infinite number of little plates or ſcales, which, by their various directions, intercept ſmall cells and web-like ſpaces; and join together all parts of the human body in ſuch a manner as not only to ſuſtain, but to allow them a free and ample motion at the ſame time. But in this web-like ſubſtance there is the greateſt diverſity relatively to the proportion betwixt the ſolid parts and intercepted cells, as well as the breadth and ſtrength of the little plates, and the nature of the contained liquor, which is ſometimes more watery,

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[3] They are very fully perceived in the oſſa bregmatis, frontis, and temporum, if the child has laboured under a hydrocephalus; and alſo in the teeth of larger animals, when the alveoli are as yet ſhut up.

and ſometimes more oily: and likewiſe to the mixture of fibres and threads; of which in ſome parts, as in the coats of the arteries, there is a great number; in other parts, as under the ſkin, ſcarce any.

X. Out of this net-like cellular ſubſtance, compacted by the little plates, concreting and preſſed together by the force of the incumbent muſcles, and diſtending fluids, or by other cauſes, ariſe broad and flat plates or ſkins in various parts of the body, which, being generally diſpoſed in a rectilineal direction, are more properly called *membranes;* or, being convoluted into cones and cylinders, pervaded by a flux of ſome juice or liquors through their cavities, put on the name of *veſſels;* or elſe, being extended round ſome ſpace that is in a plane parallel to itſelf, we call it a *tunic* or coat. But that tunics or coats are formed out of the cellular ſubſtance is proved by ocular inſpection, eſpecially in the aorta, ſkin, pericardium, or dura mater, by maceration; and thus the coats of the muſcles are evidently of a cellular fabric, ſimilar to that of other tunics. The ſame thing is alſo proved from the eaſy change of the dartos, and the nervous membrane of the inteſtines, by inflation into a cellular ſubſtance; from the hard and thick membranes about encyſted tumors, which have their origin only in the cellular texture; and, laſtly, from that membrane, which, being gradually moſt firmly compacted, forms the true ſkin lying under the epidermis, and being thence continued is partly reſolved into the ſubcutaneous cellular texture which is filled with fat.

XI. All the veſſels with which we ſee tunics painted, are an addition to the cellular net-work, and in nowiſe conſtitute the nature of a membrane, but are ſuperadded to the membrane itſelf, which is firſt formed of the cellular net-like ſubſtance. Betwixt the meſhes or ſpaces of the inteſtinal net-work of veſſels, perfectly well filled by the Ruyſchian art of injection, we ſtill ſee, that the white cellular ſubſtance which remains, greatly exceeds the bulk of the veſſels, although,

though, by their preternatural diſtenſion, they take up more room by filling more of the ſpace[4]. But with regard to membranes compounded of fibres decuſſating or interwoven with each other, I know of none ſuch; unleſs you will take the ligamentary or tendinous fibres for them, which are ſpread over ſome true membrane.

XII. This cellular web-like ſubſtance in the human body is found throughout the whole, namely, whereever any veſſel or moving muſcularfibre can be traced; and this [5] without the leaſt exception, as far as I know.

XIII. The other elementary ſubſtance of the human body (III.) which cannot be truly called either a fibrous or cellular plate, is a mere glue evaſated and concreted, not within the fibres, but in ſpaces betwixt them. In the bones this extravaſated ſubſtance is manifeſt enough: for you ſee the fibres very diſtinct in the bones of a fœtus, in the intervals between which you perceive the veſſels running; ſo that every bone in the ſkull, on all ſides, reſembles the teeth of a comb. But this fabric is ſo altered in an adult perſon, that the juice being extravaſated in the ſpaces between the fibres and the intervals thus filling up, as happens with the juice of madder, plates are then formed of the teeth above mentioned cemented together [6]. The cartilages ſeem to be ſcarce any thing elſe than this glue concreted.

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[4] Many things ſtill remain which by no means can be referred to the nature of the veſſels. They are very ſucceſsful injections, which can be thrown into the brain, lungs, glandula thyroidea, heart, thymus, kidneys, liver, gall-bladder, inteſtines, teſticle, ſkin, &c.; they leave always a great part of the fibres, in filling which the next age will not be more ſucceſsful than the preſent

[5] This is to be underſtood with ſome limitation. It is true, indeed, of ſeveral parts formed of veſſels, membranes, and fibres, that they can be reſolved by the knife, inflation, maceration, into cellular texture: But the diſſolution of a recent brain, of the cornea, and lens in water; the deſtruction of the epidermis, hairs, and nails; the ſtructure of a great part of the bones and catilages, &c. render it probable, that all the animal parts do not fully conſiſt of cellular texture alone.

[6] The oſſifications and preternatural indurations illuſtrate this parti-

XIV. But here the courſe of nature ſeems to be ſuch, that even the filamentary fibres (III.) are all firſt formed of ſuch a transfuſed glue. And, that the membranous or ſcaly fibres of the cellular ſubſtance (VII.) are thus formed appears from thoſe cellular fibres produced in the thorax from a concreted vapour, which joins the ſurface of the lungs to the pleura; for theſe perfectly reſemble the true and natural cellular ſubſtance. The ſame appears alſo from a compariſon of the fœtus with an adult; for the large ſubcutaneous cellular ſubſtance in a fœtus has in its ſtead a mere jelly interpoſed betwixt the ſkin and muſcles, which laſt we obſerve very firm in a fœtus: from the morbid diſſolution of the membranes of the muſcles into a mere glue: and from a ſimilar change into glue or ſize, made on the ſkin, tendons, and ligaments of animals by means of boiling water. This theory is alſo illuſtrated from clots of coagulated blood, the ſanguineous membranes of Ruyſch, Albinus's membranes formed of mucus, polypus, ſilk, and glue. Laſtly, that the bones themſelves are formed of compacted gluten, is ſhown from diſeaſes, in which the hardeſt bones, by a liquefaction of their gluten, return into cartilages, fleſh, and jelly: ſimilar changes are made on the bones of fiſhes and other animals by Papin's digeſter.

XV. It ſeems, then, that a gelatinous water, like the white of an egg, with a ſmall portion of fine cretaceous earth, firſt runs together into threads, from ſome preſſure, the cauſes of which are not our preſent concern. Such a filament, by the mutual attraction of coheſion, intercepting ſpaces betwixt itſelf and others, helps to form a part of the cellular net-like ſubſtance, after having acquired ſome toughneſs from the neighbouring earthy particles, which remain after an expulſion of the redundant aqueous glue. And in this

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particularly; which are obvious every where, as in the veſſels, and more frequently the aorta, larynx, glandula pinealis, dura mater, &c.

this net-like ſubſtance, wherever a greater preſſure is impoſed on its ſcales or ſides, they turn into fibres and membranes or tunics; and in the bones, laſtly, they concrete with an unorganiſed glue (IV.). Hence, in general, all parts of the body, from the ſofteſt to the hardeſt, ſeem to differ no otherwiſe than in this, that the hardeſt parts have a greater number of the earthy particles more cloſely compacted, with leſs aqueous glue; whilſt in the ſofteſt parts, there is leſs earth and more glue.

CHAP. II.

Of the Cellular Substance *and its* Fat.

XVI. THE cellular fabric is madeup of fibres and plates (IX.), which are neither hollow nor vaſcular, but ſolid; although it is painted by an acceſſion of veſſels. But the principal differences of this fabric are the following[7]. In ſome parts of the body it is open and looſe, being formed of long and diſtant plates; in others it is thin and compact, being made up of ſhort concreted fibres. I find it ſhorteſt betwixt the ſclerotica and choroides of the eye, and betwixt the arachnoides and pia mater of the brain. I alſo find it tender, but more conſpicuous, betwixt every two coats of the inteſtines, ſtomach, bladder, and ureters; in the lungs, where it obtains the name of veſicles; under the pulp of the glans penis; and between the ſmall kernels of the viſcera and glands. It is compoſed of longer fibres, where it is extended over the larger veſſels, under the name of *capſule* or *vagina;* as throughout the viſcera, and particularly the liver and lungs; and is vaſtly

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[7] All the cellular texture may be divided into three claſſes: 1*mo*, The looſe and large, whether it comprehends the fat or not; it for the moſt part connects the larger parts of the body, the muſcles and viſcera: 2*do*, The ſhort and cloſe, conjoining the tunic of the membranous viſcera and the glands: 3*tio*, The confuſed, from which various membranes ariſe, as the nervous coat of the inteſtines and veſſels, pleura, albuginea teſtis, peritonæum, &c.

[illegible] between the [illegible]

firmer in the veſſels which go to the head and joints. Its principal uſe is to bind together the contiguous membranes, veſſels, and fibres, in ſuch a manner as to allow them a due or limited motion. But the cellular ſubſtance, ſo far as we have hitherto deſcribed it, hardly ever receives any fat; it is moiſtened by a watery vapour, gelatinous and ſomewhat oily, exhaled out of the arteries, and received again into the veins. The truth of this is eaſily demonſtrable from injections of oil and water, either alone or with fiſh-glue, made in all parts of the body. When this vapour is wanting, the ſmall fibres grow one to another, and the contiguous membranes or plates are cemented into one, with a loſs of their motion.

XVII. The cellular texture is more lax, and formed of plates rather than fibres, where it divides the muſcles and all their fibres, even to the ultimate fibre; where it ſurrounds and ſuſtains the leaſt veſſels with their free motion; and within the cavities of the bones, where it is alſo made up of bony plates with membranous ones intermixed. It is likewiſe very lax under the ſurface of the body, being every where interpoſed betwixt the muſcles and the ſkin; but it is laxeſt of all in the genital parts of the male, which are ſurrounded with very wide cells.

XVIII. Into the empty ſpaces of this cellular texture (XVII.) is poured almoſt every where in the fœtus, firſt a gelly, then a grumous, and laſtly a clotted fat, all under the ſkin, and in its ſmall hollows. It is compoſed of an inſipid inflammable liquid, lighter than water, which in a cold air concretes into a ſolid eſpecially about the kidneys; and in graminivorous animals, in fiſhes, probably alſo in man, while they are alive, it is very nearly fluid, although apt to be indurated. In it, along with the oil, is united an acid ſalt in quantity almoſt equal to the ſixth part of the oil.

XIX. Through this cellular texture the blood-veſſels run and are divided; from the arterial extremities of which the fat is depoſited, and abſorbed by the veins. This paſſage, from the arteries into the adipoſe cells, is ſo free and ſhort, that there muſt needs be very large mouths by which they open, and by which they give admittance to injected mercury, air, water, diſſolved fiſh-glue or jelly, and oil not excepted, which is always very ſluggiſh in paſſing through the veſſels even of living animals. Theſe are ſecreted not by any long ducts, but tranſude on all ſides through the whole extent of the veſſel; inſomuch that, when an artery is filled or injected with water, there is no part of the ſurrounding cellular ſubſtance but what ſwells with the moiſture. The warm fat, during the pulſation of the arteries, eaſily finds out the ſame paſſages. How quickly it is collected appears from the ſpeedy renovation of it, by a returning fatneſs after acute diſeaſes.

XX. But that this fat is abſorbed by the veins, we are taught from the ſudden effects which exerciſe of the muſcles more eſpecially has in conſuming the oil of very fat animals; alſo from the conſumption of our fat in fevers; from the cure of dropſies, where the water transfuſed into the cellular ſubſtance is in a manner abſorbed and thrown out by the inteſtinal tube; and, laſtly, from the tranſuding of water and oil from the venous orifices, when injected by the ſyringe. Are the nerves ſpread out upon the adipoſe cells? It is certain they in moſt parts run through this ſubſtance, and divide into the minuteſt filaments, ſo ſmall that you can no longer trace them by the knife: that they are loſt in it, is not probable[8]; for the fat is both inſenſible and unirritable.

XXI. The intervals betwixt the plates of the cellular membrane, are every where open, and agree in forming one continuous cavity throughout the whole body.

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[8] It is certain that no nerves remain in the fat. In the very ſlender delicate laſhes which pierce the ſoft fat of the orbit, in the infinite diſtributions of the crural and ſciatic nerve through the fat of the femur, &c. the exit of nerves from the fat to other parts is fully apparent.

body[9]. This appears from the inflation which butchers, and likewiſe the ſurgeons of Ethiopia, produce by a wound of the ſkin, and which raiſes the ſkin all over the body; alſo from an emphyſema, in which the air received by a wound of the ſkin, being retained, cauſes a ſwelling throughout the whole ſurface of the body; the paſſage of bodies, put under the ſkin, to a place remote from that at which they entered; the paſſage of pus from an inflamed place to remote ulcers; and, finally, from diſeaſes, in which a watery or ſerous humour is depoſited into all the cells of this net-like ſubſtance throughout the body, and is emptied from them all by a ſingle inciſion. That none of the cellular fabric is excepted from this communication, appears from caſes, wherein the vitreous body of the eye has received the flatus of an emphyſema; and again from diſeaſe, in which the gelatinous ſerum of a dropſy has been found transfuſed even into the cavernous bodies of the penis.

XXII. The great importance and uſe of this cellular ſubſtance in the animal fabric, muſt be evident to all who conſider, that from this part alone proceeds the due firmneſs and ſtability of all the arteries, nerves, and muſcular fibres of the body, and conſequently of all the fleſhy parts and viſcera formed from thence; even the figures of the parts, their proper length, curvatures, cavities, and motions, depend entirely on the cellular texture, which is in ſome places of a lax, in others of a harder fabric; for when it is cut, the parts lengthen and are relaxed: Of this ſubſtance, along with the veſſels, nerves, muſcular and tendinous fibres (of which it alone compoſes a good part), all the viſcera, muſcles, and glands, with their ligaments and capſules, are compoſed. It alone, its various length, tenſion, quantity and proportion, occaſions the difference in the glands and viſcera; and, laſtly, it is it alone which makes the greateſt part of the body itſelf, if indeed the body is not totally formed of ſuch cellular filaments.

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[9] The cellular texture, juſt as the utricular ſubſtance in vegetables, communicates through all the cells of the animal body.

XXIII. This ſubſtance hath a contractile power, different from that of irritability, which, though not demonſtrable by experiments, for the moſt part diſpoſes the cellular fibre to ſhorten itſelf gradually after it has been lengthened. This power, excited by cold, renders the ſkin rigid; raiſes the hairs; draws up the ſcrotum; and, after geſtation[10], reſtores the ſkin of the abdomen and the uterus to their former ſize[11]. The ſame force, by a gentle but continual contraction, promotes the ſecretion both of the fat, the liquors of the ſubcutaneous and other glands, and of pus: in the veins and receptacles, it reſiſts dilatation; which being taken off, it reſtores the part to its former ſize. In the fœtus, this gentle force is among the principal cauſes of the changes that happen to the body.

XXIV. The *uſes* of the fat are various; as to facilitate the motions of the muſcles, in all parts to leſſen their attrition againſt each other, and to prevent a ſtiffneſs or rigidity: it fills up the intermediate ſpaces betwixt the muſcles, with the cavities about many of the viſcera, in ſuch a manner, that it readily yields to their motions, and yet ſupports them when at reſt: it principally conſtitutes the weight of the body; conducts and defends the veſſels: it gives an uniform extenſion to the ſkin; and, ſerving as a cuſhion to eaſe the weight of the body, renders the whole of a comely, agreeable ſhape: probably, by mixing with many of the humours, it abates their acrimony: it has a principal ſhare in forming the bile; and by tranſuding through the cartilaginous incruſtations of the bones, it mixes with the articular liquid, and by re-abſorption it lubricates their fibres: by exhaling through the pores of the ſkin, it reſiſts the inclement drying quality of the air: alſo, by exhaling in a living perſon from the meſentery, meſocolon, omentum, and round the kidneys, it lubricates the ſurfaces of the viſcera with an oily emollient vapour; and, by interpoſing itſelf between their integuments, prevents their concretion.

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[10] And in dropſical caſes, after a cure has been performed.

[11] And reſtores to the mammæ, after ſuckling, their agreeable form and beauty.

XXV. The fat is depoſited into the cells of this ſubſtance by ſleep, reſt of body and mind, and a diminiſhed force of circulation[12]: whence, being collected in too great a quantity, it proves injurious by compreſſing the veins; and, by cauſing too great a reſiſtance to the heart, it makes a perſon ſhort-breathed, and liable to an apoplexy or dropſy. The ſame humour is taken up by the veins; and, being rapidly moved along the arteries, is conſumed by violent exerciſe, venery, watchings, cares of the mind, a ſalivation, diarrhœa, fever, faſting, or ſuppuration. When reſtored to the blood, it increaſes acute diſeaſes, tinges the urine, and forms a part of its ſediment. After a ſudden conſumption of it, it is ſoon renewed again from good juices, or healthy humours: but, in a languid habit, a gelly, inſtead of fat, is depoſited into the cells; and this cauſes the dropſy we call anaſarca, and an external hydrocele or watery ſwelling.

CHAP. III.

Of the Vessels.

XXVI. THE membranes will be better deſcribed ſingly. There are ſeveral common to the *arteries*. Theſe are long extended cones, whoſe diameters decreaſe as they divide into more numerous branches: but where the arteries run for ſome length, without giving off large branches, their convergency, if any, is not very evident: at length they are cylindrical, or very imperceptibly diminiſhed, when they are called capillaries, and wherever they admit only a ſingle globule; the ſection being every where without exception circular, in a diſtended artery. Where they ſend off large branches, the light or cavity is there ſuddenly diminiſhed, inſomuch that they might be taken for a chain of cylinders, of which every one is narrower than the preceding. If you reckon them cones, then the common baſis of the cone in all arteries is either in the one or the other ventricle of the heart; and the apex of the cone terminates either in the beginning of the veins, or in the beginning of the cylindrical part of the artery, or in the exhaling veſſel, unleſs it is cylindrical. In ſome places they ſeem to diverge or dilate; at leaſt they become there of a large diameter, after they have been filled or diſtended with wax; which poſſibly may ariſe from ſome ſtoppage of the wax, by whoſe impulſe that part of the length of the artery becomes more diſtended than the reſt. Examples of this kind we have in the vertebral artery, at the baſis of the ſkull [13], in the ſplenic artery, in the flexure of the carotid artery, according to Mr Cowper's injections; and, laſtly, unleſs theſe experiments deceive me, in the ſpermatic arteries [14] in all places, likewiſe, where the ramifications between the diameter of the artery is a little increaſed.

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[12] And diſeaſes of the liver, ſince the circulation is remarkable during ſleep, the increaſe of the fat, and the propenſity to dropſy and hepatic affections.

XXVII. There is *no external coat* proper and perpetual to all the arteries; but the office of ſuch a coat is ſupplied to ſome of them by one ſingle external and incumbent integument, which in the thorax is the pleura, and in the abdomen the peritonæum. In the neck, arm, and thigh, a ſort of thicker cellular ſubſtance ſurrounds the arteries. The membrane of the pericardium, which on all ſides ſurrounds the aorta, returns back with the veſſels to the heart. The dura mater imparts a capſule, that ſurrounds the carotid artery as it paſſes out through a hole in the ſkull. But the firſt true external membrane common to the arterial tube in all parts of the body, is the cellular ſubſtance,

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[13] In the baſilar artery, ſo called.

[14] In the artery of the arm a little above the diviſion.

ſtance, which in ſome parts (as in the thorax) we ſee repleniſhed with fat.

XXVIII. This *cellular coat* is, in its external ſurface, of a *more lax* texture, painted with a great many ſmall arteries and veins; and it has nerves runnning thro' its ſubſtance, which are none of the ſmalleſt. There is ſometimes ſo much of this cellular ſubſtance about the artery, as might occaſion one to think it hardly belonged to it as an external coat or lamella, but rather as ſome foreign net-work added to this veſſel. Thus we find it in the arteries of the neck, groins, and ſubclavians; in the meſenteric, cæliac, and hepatic arteries; where it is chiefly interwoven with long fibres. And theſe are the vaginæ or capſules of the arteries, formerly obſerved by ſome eminent anatomiſts [15].

XXIX. As this *cellular coat* advances more inward, and nearer to the light and capacity of the artery, it becomes *more denſe*, ſolid, and is tied more cloſely together by a kind of wool, and may be called the *proper coat* of the artery. That there is no tendinous coat of the arteries diſtinct from this laſt part of the cellular ſubſtance, is evident from maceration, whereby the inner ſtratum of this arterious tunic changes into a cellular fabric [16].

XXX. Within the former, and nearer the light or capacity of the artery, it has *a coat of muſcular fibres*, which are in general imperfect circles: that is to ſay, no fibre any where makes a complete circle round the veſſel; but a number of ſegments conjoined together, with their extremities turned off ſidewiſe, ſeem to form one ring round the artery. Theſe fibres, in the larger arterial trunks, form many ſtrata, appear of

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[15] Theſe additions of ſmaller veſſels to the greater, which ſome people have miſtaken for a peculiar vaſcular tunic, are the more frequent the younger the animal, or if it has laboured under a congeſtion, or died of ſuffocation.

[16] Soluble, according to Albinus's way, almoſt into as many lamellæ as you chooſe, without any evident number or diverſity.

a reddiſh colour, and are remarkably firm and ſolid; but in the ſmaller arteries they are by degrees more difficult to demonſtrate, and ſeem to be wanting in the arteries of ſmall animals. I have never obſerved them to run along the veſſel lengthwiſe. Under theſe membranes, but pretty difficult to demonſtrate, is an exceeding ſhort cellular texture, into which a chalky concreting matter is poured when an artery oſſifies.

XXXI. The *innermoſt coat* of the artery is thin, and finely poliſhed by the influent blood; ſo as to form a ſingle incruſtation that every where lines the fleſhy fibres, which are not very continuous one to the other, and prevents the blood from inſinuating into the ſpaces betwixt them. It is every where ſmooth and without valves; although, from a ſort of mechanical neceſſity, ſometimes certain folds, raiſed into a ſemicircle at the origination of branches, form a projecting eminence; as we ſee at the branches produced by the arch of the aorta. Yet, in arteries of the viſcera, the innermoſt coat is ſofter, lax, wrinkled, and almoſt friable, eſpecially in the ductus arterioſus.

XXXII. The arteries themſelves *have arteries* which are more particularly ſpread through their external cellular coat; and, ſpringing on all ſides from the next adjacent ſmall arterial trunks, from numerous branchy net-works, which are all of them indeed very minute, but plainly appear, even in the fœtus, without injection, to be very numerous. There are alſo *nerves* which deſcend for a long way together through the ſurface of the artery, and at laſt vaniſh in the cellular ſubſtance of the veſſel; of which we have a ſpecimen in the external and internal carotids and arch of the aorta[17]. And from theſe, do not the arteries ſeem to derive a muſcular and convulſive force, very different from that of their ſimple elaſticity? Does not this force ſhow itſelf plainly enough in fevers, faintings, palſy, conſumption, and paſſions of the mind? But the artery is in a manner inſenſible and unirritable [18]; and if it is conſtricted by the application of poiſons, it has this in common with the dead ſkin.

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[17] But this is very remarkable in the nerves, ſo called, molles and cardiaci, that they ſurround the arteries of the head and large veſſels of the heart. In the plexus pulmonalis ariſing from the vagum, the meſenteric from the ſplenic, the facial from the durum, the frontal from the fifth, the femoral from the anterior cruralis,

XXXIII. The *ſections*, or diviſions, of arteries ſhow themſelves with a round light or hollow capacity, becauſe they are elaſtic; and this is the reaſon why, from the ſmall arteries of the teeth, hæmorrhagies are ſometimes fatal. The aorta, indeed, of the thorax and abdomen, the carotids of the neck, and ſome other arteries of the dead body, from their leſſened extenſion, appear ſomewhat flat or depreſſed; but their round figure, or circular ſection, is every where reſtored by injection. *Their elaſticity* is alſo evident in that powerful compreſſure, which a ſegment of a large artery makes upon the finger that diſtends it, and which is much ſtronger in a dead than in a living body. In the living body, indeed, this force yields to that of the heart; but inſtantly recovers itſelf when the heart is relaxed, and reſtores the artery to its former diameter; and this makes the *pulſe*, whoſe full explication ought to be preceded by a hiſtory of the heart: at preſent it may ſuffice to ſay, that all the arteries have this pulſation, although the ſyſtole and diaſtole thereof can be perceived by the finger, only in the larger, not in the ſmaller ones naturally; and in the ultimate inflection of the arteries, the pulſe totally vaniſhes; but, by an increaſed motion of the blood, even the leſſer arteries make a violent pulſation, as we ſee in an inflammation [19]. Theſe veſſels ſtrongly contract lengthwiſe, and are rendered ſhorter on diſſection.

XXXIV.

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cruralis, it is manifeſt that they accompany the veſſels, and ſpread out an infinite number of branches through their tunics.

[18] This opinion of the irritability of the veſſels has been limited from later experiments.

[19] Or on preſſure depending on an external cauſe.

XXXIV. The *ſtrength* of the arteries is conſiderable enough: but as the denſe hard net-work of the outer cellular coat refuſes to yield to a diſtending force, it breaks without much difficulty, almoſt eaſier than the coats of the veins; and from thence ariſe aneuriſms. But, in general, the trunks are, in all parts of the body, weaker, and the branches ſtronger, in their coats; whence the impulſe of the blood may exert a conſiderable effect upon the former, but leaſt of all on thoſe of the limbs. From hence it is, that aneuriſms are moſt frequently formed near the heart; for, in the lower extremities, the ſtrength of the arteries, and of the veins too, is much increaſed, as well as in the ſecreting organs.

XXXV. With regard to the *courſe and general diſtribution* of the arteries, nature has every where diſperſed them through the whole animal body, except in a few membranes. But ſhe hath diſpoſed of the trunks every where in places of ſafety; becauſe wounds cannot happen to the ſmaller of them without danger, nor to the larger without loſs of life. The ſkin is ſpread with numerous ſhort and ſmall arterial trunks; but the larger ones, defended by the ſkin and muſcles, creep along near the bones. In general, the arteries are in proportion to the parts of the body to which they are ſent. The largeſt go to the ſecretory organs, the brain, and ſpleen; the leſſer ones to the muſcular parts.

XXXVI. The proportion of the light or cavity of the artery to its ſolid part is not every where the ſame, nor is it conſtant even in the ſame artery. This proportion, in the firſt place, is leaſt ~~of all~~ at the heart, and increaſes as the arteries remove farther from it. Secondly, in a full-fed plethoric animal, whoſe blood paſſes freely, and with great force thro' its arteries, the proportion of the ſolid parts of theſe veſſels is leſs than in a famiſhed extenuated creature, whoſe blood hath a feeble motion. [illegible] natural

XXXVII. From the trunks of all the arteries branches are ſent forth, and from theſe again proceed leſſer twigs by a numerous diviſion, of which you can ſcarce find the end, though you may perhaps count twenty ſubdiviſions of this kind. Here the lights or ſections of any two branches taken together, always exceed the light of the trunk from whence they come, in nearly a ſeſquilateral proportion, or as one and a half to one, or ſomewhat leſs. Alſo every trunk juſt above its diviſion is ſomewhat broader or more expanded. The angles, at which the branches go out from their trunks, are generally acute, either half right angles or nearly ſo; to the forming of which angles, as we ſee in mechanics, there is required the longeſt projection. Inſtances of their going off at right angles, or nearly ſo, we have in the lumbal or intercoſtal arteries; of their going off in a retrogade or reflected courſe, we have one inſtance in the coronaries of the heart, and another inſtance in the ſpinal arteries, which are produced by the vertebrals. But, generally ſpeaking, thoſe which are eſteemed retrogade or reflexed, were ſent off, at their origin, in acute angles; ſuch as the aſcending artery of the pharynx, the deſcending one of the palate, the umbilical mammary arteries, and the nutritious ones of the large bones. Laſtly, we often obſerve large branches ariſing under leſſer angles, and ſmaller ones under greater angles: but it is rarely that we obſerve two arteries of a large diameter run together into one trunk. An example of this, however, we have in that artery which is formed out of the vertebrals: in the ſmaller ones it is frequent, as in both the ſpinal arteries, and that of the ſincipital foramen. In many parts, the arteries have repeated alternate undulations or flexures, as they run on in a ſpiral courſe, wherein we ſee their diameter often conſiderably enlarged, as in the large inteſtines, womb, face, ſpleen, lips, and iris. Even the ſtraight arteries in other places, if too much diſtended, fall into ſerpentine flexures. Sometimes they are ſuddenly twiſted into a kind of circles, as the carotids under the mamillary proceſs.

Strange
to one

XXXVIII. The artertes are frequently conjoined by intermediate *branches*, in ſuch a manner, that the twig of ſome certain artery ſhall run to meet one of the ſame kind from another neighbouring artery, and, by joining together with that, form one trunk. Inſtances of this kind we have among the large trunks in the inteſtines, among the middling ones in the kidneys, womb, &c. and among the ſmaller in all parts of the body; inſomuch that there is no part of the human body, wherein the neighbouring arterial trunks, whether of the ſame or of different denominations, do not form anaſtomoſes or joinings one to the other by intermediate branches. Of rings diverging laterally from the arteries, and returning into themſelves, we have inſtances in the eye and brain. The extremities of the arteries, which are either cylindrical or nearly ſo, ſend off ſmaller branches, which, for their extent, are more numerous and generally diſpoſed like a net; ſo that each branch, by its ſmaller twigs, forms anaſtomoſes with thoſe of its neighbouring branches: and thus we find it in all membranes. By this means it happens, that, though the paſſage from the heart to any part of an artery is obſtructed, the blood may nevertheleſs flow through the neighbouring arteries into all the branches of the obſtructed one. Thus a gangrene or languor of the part is very ſtrongly prevented, and the obſtruction is more eaſily reſolved by the repulſion of the obſtacle into the larger part of the trunk.

XXXIX. Laſtly, one of the leaſt arteries is either changed by a continuation of its canal into a vein, in ſuch a manner, that the ultimate little artery, which is generally reflected, having ſurpaſſed the angle of its reflection, becomes now a ſmall vein; or elſe a branch, ſent out at right angles from the artery, is inſerted under a like angle into the branch of a ſmall vein. Both theſe kinds of mechaniſm are demonſtrated to us by the microſcope, and the eaſy return of injections through the veins into the arteries. And theſe vaſcules we ſee ſometimes large enough to receive only one, and ſometimes ſeveral blood-globules at a time. A large artery is never obſerved to open into a vein.

XL. *In the viſcera*, we find the ſmall arteries diſpoſed not ſo much in net-works as in a different fabricature, wherein the ſmall branches deſcend very thick, or in cluſters, parallel to the trunk, ſo as to reſemble bruſh pencils, a variety of little trees or buſhes, ſmall ſerpents, or threads, according to the various diſpoſition of the parts.

XLI. Sometimes the arteries end in another manner, namely, by being converted into veſſels of the ſmaller kinds. Theſe are ſometimes continuous to the arteries and real arterial trunks, as will be obſerved in the ophthalmic artery, upon tracing the arteries of the tunica choroides, or the colourleſs ones of the circle of the uvea and iris. That a net-work of pellucid arteries is continuous with the red branches of the ophthalmic one, is evident from inflammations, and the redneſs of the parts when relaxed by vapour or by cupping; from repletion, and the microſcopical experiments of Lieberkuhnius upon frogs, in which colourleſs globules were ſeen to paſs from a red artery into a lateral veſſel. In a fabric of this kind the red blood is eaſily forced into the ſmaller veſſels.

XLII. In other places the ſmaller veſſels ſeem to proceed laterally as branches from the trunks of the leaſt ſanguineous arteries, and are drawn out into trunks ſtill ſmaller. Theſe are called *excretory ducts*[20]. It is with difficulty that theſe veſſels are filled with red blood; of this, however, we have examples in the kidneys, the liver, and breaſts. Indeed the blood, when vitiated, penetrates the excretory ducts of the whole body, even without hurting the veſſels; nor is that aberration found to be productive of any evil conſequence after the diſorder of the blood is cured.

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[20] I would rather call them ſecretory; for they properly carry a liquor to be ſecreted from the blood to the ways and places of excretion. I have almoſt always ſeen mercury, diſſolved fiſh-glue, or turpentine, when injected into the arteries after tying the veins, flow from the biliary, ſalival, urinary, and lactiferous ducts; but there is at the ſame time an eaſy paſſage of pure blood through the ſame canals.

XLIII. Another termination of the arterial extremities is *into the exhaling veſſels;* and this is a manner of their ending very frequently to be obſerved in all parts of the body. The whole ſkin, all membranes of the human body, which form any cloſe cavity, all the ventricles of the brain, the anterior and poſterior chambers of the eyes, all the adipoſe cells and pulmonary veſicles, the whole cavity of the ſtomach and inteſtinal tube, through which the air has a paſſage, are all of them repleniſhed with exhaling arteries of this kind. Theſe emit a thin, watery, gelatinous humour, which, being collected together by ſtanding, ſometimes makes no inconſiderable quantity; and, particularly by diſeaſe or death, is converted into a watery, but coagulable lymph. The truth of this is eaſily demonſtrable from the watery ſweat that enſues after injecting the arteries with that liquor warm. In ſome places, indeed, they exhale not a thin vapour, but blood itſelf, as we ſee in the heart, the cellular fabric of the penis, urethra, clitoris, and nipple of the female breaſt; in all which the blood itſelf is naturally poured out. Does not every ſecretion, that is made in true glands or hollow cryptæ, bear ſome analogy to this exhaling fabric?

XLIV. Whether or no, in all parts of the human body, do the pellucid veſſels, ariſing from the ſanguine ones, and carrying a humour thinner than blood, again ſend out ſmaller veſſels, to be ſubdivided into ſtill leſſer orders? We ſeem, indeed, not to want examples of this in the manner propoſed to us by the moſt celebrated profeſſors[21]. That the aqueous humour

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[21] I have ſeen beyond all diſpute, a new riſe of blood-veſſels, where before they were inviſible. This is very clear in the chemoſis; but I have alſo obſerved a net-work of veſſels on the inner ſurface of the dura meninges in a woman, who had a very large glandula

humour is ſeparated by very fine veſſels, generated from the colourleſs arteries of the iris, is very probable. That the red-coloured veſſels in the cortical ſubſtance of the brain, ſeparate a juice pervading the medullary ſubſtance, by the intermedium of another order of veſſels, we are almoſt certain. And the like we are perſuaded from an eryſipelas or yellow inflammation, ariſing from the yellow or ſerous globules impacted into ſmaller veſſels.

XLV. It may then be aſked, if there are not yellow arterious veſſels of a ſecond order, which ſend off lymphatic ones of a third order, from whence by degrees ſtill leſſer kinds of veſſels branch out? Such a fabric does not ſeem agreeable to the very eaſy tranſition that is made by the blood, mercury, or wax, into the exhaling and perſpiratory veſſels, or into the uriniferous tubuli, with the adipoſe and pulmonary cells; nor is it very difficult for the blood to ſtray into the lactiferous, lymphatic and lachrymal ducts, whither it ſhould ſeem not able to penetrate, if it went through any other intermediate vaſcular ſyſtem ſmaller than the blood-globules, which make the ſame journey. Nor can it be admitted, from the great retardation, which the humours muſt, in a third order of veſſels, meet with from this mechaniſm, and which is continually to increaſe in proportion to their diminiſhed ſize.

XLVI. The VEINS, in many particulars, reſemble the arteries[22]. There are ſix, of which two anſwer to the aorta, and the remaining four to the pulmonary artery. Their baſis is in the ventricles of the heart, and their apices in the extremity of each branch, through all parts of the body, excepting one inſtance in

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glandula thyroidea, which by compreſſing the jugular veins obſtructed the regreſs of the blood from the cranium: the ſame thing happens upon the lungs, liver, and other viſcera.

[22] We ought to count ſeven trunks of veins; for the vena portarum, conducting its contents through ſo many windings, at length pours them into the venæ hepaticæ: ſo that it is altogether to be reckoned a very ſingular trunk.

in the liver. And, in a great number of parts they run parallel with the arteries, one by the ſide of the other; but yet they differ from the arteries in various reſpects.

XLVII. The fabric of the veins is ſlender, every where ſmooth, difficultly ſeparable into diſtinct coats or membranes, like the arteries; and the cellular texture ſurrounding this fabric is very eaſily diſtended. This fabric, both above and below the heart, is ſurrounded, except in one place, with muſcular fibres. Every where, however, it is lax like the cellular texture of the arteries by which they are joined to the other parts of the body. Notwithſtanding this ſlender fabric, the veins are every where ſufficiently firm, and do not eaſily burſt with inflated air; being, in moſt inſtances, ſtronger than the arteries themſelves. But they burſt much more eaſily in living than in dead animals, as appears from morbid inſtances in the arm, face, leg, thigh, &c.[23] Nor do they ſupport themſelves like cylinders after being divided, but they collapſe together, ſo as to make their light or capacity appear like a ſlit; except they are ſuſtained and hindered from thus collapſing by ſome ſtronger cellular ſubſtance placed round them, as we ſee in the liver and womb. They are but ſlightly irritable, unleſs the ſtimulus be of the chemical or more acrid claſſes; for, in that caſe, they contract themſelves with a convulſive force greater than that of the arteries. They have no pulſation, if we may truſt all accounts, unleſs the venous channel is ſomewhere obſtructed; or when, in dying people, the blood is thrown back again from the right auricle into the deſcending and aſcending cava, or when falling back from the brain.

XLVIII. The veins are much larger than their correſponding arteries, having the ſquare of their diameter often double or triple, and almoſt quadruple; as near as the emulgents and veſſels of the kidneys. In general, however, the diameter of the veins is to

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[23] I know very lamentable caſes of ruptured varices in different places in child-birth.

to that of the arteries as nine to four; yet the capacity of the capillary veins but little exceeds that of the arteries which accompany them. They differ likewiſe from the arteries in their diviſion, having more numerous trunks and branches[24]; for to one artery in the limbs, we uſually meet with two veins. The larger veins are alſo branched in a more net-like diſpoſition, by forming more frequent anaſtomoſes one with another; for not only the ſmaller branches, but even the larger trunks, of the veins, are conjoined one to the other within its neighbourhood, upper with lower, and right with left, by apparent inlets or inoſculations. They affect to run near the ſurface of the body; and through the limbs, neck, and head: they run a long way covered with little more than the bare ſkin, which is a circumſtance we very rarely obſerve in arteries; and, for the ſame reaſon, they often go out in their courſe, to a conſiderable diſtance from the arteries. For, in this caſe, the veins follow the ſurface of the parts next the ſkin, without their correſponding artery, which, in the mean time, deſcends to a conſiderable depth, attended in its courſe by ſome ſmaller venous branch. In the ſmaller branches of the veſſels, where they make net-like diſpoſitions in the membranes and the internal fabric of the viſcera, the veins and arteries commonly run contiguous one to the other; but here the veins have generally a leſs ſerpentine or inflected courſe.

XLIX. In the larger ſanguineous veins, little valves are found in great plenty. The innermoſt membrane of the vein, being double, riſes into the cavity of the veſſel like a curtain, ſtretching itſelf farther along the vein every way, ſo as to form what may be called a kind of little horns; but the baſis, which is the part that ſuſtains the weight of the blood, is ſtrongeſt, and grows out of the vein in the ſhape of a circular ſegment. Theſe, joined with the ſide of the proceeding vein, intercept a ſpace of which the outer ſide is the vein itſelf, and the inner the valve, which, by its convexity, ſtands out within the bore of the vein; ſo that the parabolic ſpace or hollow mouth of the valves always looks towards the heart: they are found in all the ſubcutaneous veins of the limbs, in thoſe of the neck, face, tongue, and in the veins of the penis: at the origin of the larger branches there are two, three, four, and ſometimes five of them together, while in their ſmaller branches they are only ſingle. There are none of theſe valves in the deep-running veins of the viſcera; and, therefore, none in thoſe of the brain, lungs, heart or liver, or through the whole ſyſtem of the vena portarum[25], nor in the kidneys or womb (except one or two valves in the ſpermatic vein); nor, laſtly, are there any in thoſe ſmaller blood-veins, which are of a leſs diameter than the twelfth part of an inch. Sometimes, though rarely, they are found in the vena azygos[26], and at the mouths of the hepatic and renal veins: there I have ſeveral times obſerved a ſort of wrinkles in the place of valves. In the ſmaller venous branches there are a ſet of long, ſharp-pointed or parabolical valves, of a more extended figure as the vein is ſmaller: and theſe make a greater reſiſtance than the larger valves, to hinder the blood from returning back upon the parts.

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[24] There are examples almoſt every where in the body, particularly in the ſmaller veins; but even in the larger they are to be found, as the external jugular, vena portarum, azygos, cephalic and baſilic, magna ſaphena, with which no arteries correſpond.

L. The veins have their origin, as we ſaid before, from the terminations of the arteries. They ſometimes ariſe by a continuation from the inſerted branches, or from a reflection of recurved trunks of the ſmalleſt arteries[27]. Others again are either continued from veins leſs than thoſe which carry blood, or elſe receive additions and roots from them; as we ſee, for inſtance, in the lymphatic veins of the thoracic duct. Others of a bibulous kind take their origin from the abſorbing veins, that are diſperſed all over the ſurface of the body, as in the chambers of the eyes, the cavities of the inteſtines, bladder, womb, breaſt, peritonæum, pericardium, and ventricles of the brain. From theſe a watery ſweat iſſues, by injecting the venous trunks with that kind of liquor, which may be eaſily imitated throughout the whole human body: hence water, jelly, or oil[28], diſtil from the vena portarum into the cavity of the inteſtines; hence alſo water, injected into the abdomen of a living animal, quickly vaniſhes: but of theſe things we ſhall ſpeak more largely in a proper place.

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[25] In the ſyſtem of the vena portarum of many quadrupeds, I have found numerous valves; and on that account was unable to fill the veins of the inteſtines, as in man, through the trunk of the vena portarum.

[26] Not before the ramifications of the azygos touched the muſcles; for they commonly there reſiſted my injection.

[27] It is proved from microſcopical obſervations on fiſhes, from the

LI. From the former thoſe veins do not much differ, which, ariſing in all parts of the cellular membrane, return thin vapours, dropſical waters, diſſolved fat, or extravaſated and corrupting blood, and the poiſon of opium introduced into the cellular texture, again into the maſs of the blood; or which reabſorb and return the blood itſelf from the cellular fabric of the penis, clitoris, or nipples of the breaſts after coition. And that inhaling veins of this kind open into all the glands, is highly probable; where, by abſorbing the thinner humour, they leave the remaining maſs of a thicker conſiſtence; of which we have inſtances in bile, ſemen, mucus, &c.

LII. That there are veins of a *ſmaller claſs*, but reſembling thoſe which convey blood, appears from the ſame experiments which demonſtrate the pellucid arteries: thus in the iris of the eye there are ſmall veins, and not a few in the adnata tunica of that organ;

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the very eaſy paſſage of the blood from the arteries into the veins, and ſucceſsful injections of the veins through the arteries, that by far the greateſt part of the veins ariſes from the arteries without any body intervening.

[28] No liquid has a more eaſy tranſit from the veins into the inteſtines than mercury has, whoſe effects I have often enough experienced.

gan; nor is it to be doubted that, in a healthy body, ſmall pellucid veins[29] may be found in the vitreous body of the eye itſelf.

LIII. But, in moſt parts of the human body, are found other veins[30], full of a reddiſh, yellowiſh, or almoſt pellucid liquor, coagulable by heat; which veins, being formed of very tender coats, have a degree of irritability from any chemical or very acrid ſtimulus. They have very frequent valves or partitions, which make them ſeem in thoſe places jointed or knotted like a reed when they are turgid; theſe, by degrees, meeting together, either all or moſt part of them empty their contents into the thoracic duct. They ariſe from the cellular texture throughout the whole body, as I long ago learned concerning the lactiferous veſſels of the breaſts, the vaſa efferentia of the teſticles, the lymphatics which originate from the meſenteric glands; and as is now ſhown to be the caſe with the lymphatic veſſels of the teſticles, ſpleen, and other parts. From analogy, eſpecially from hydropical appearances, it is very probable that they ariſe likewiſe from the large cavities of the body; nor is it improbable that this kind of veſſels receive a thin humour from veins of the ſmalleſt ſize. But all the lymphatics, in their courſe, meet together in a peculiar kind of conglobate glands, into which they enter; and, from the ſhape of veins, becoming arterial, or like converging cones, they divide into ſmall branches, and then proceed to meet together again in other little trunks.

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[29] I have obſerved both from anatomical injections, and from inflammation, thoſe numerous veins of the capſule of the lens, and of the vitreous humour.

[30] A new genus of veſſels, to be diſtinguiſhed from others by the name of *abſorbents*, undoubtedly pervades the whole body, whoſe knowledge, ſtudy, and accurate inveſtigation, throws light upon the whole ſcope of medicine. It is out of all doubt, that it is different from the ſanguiferous veins, nor can they be filled through the ſame; and if we take into account all the experiments which have been ſet on foot by Jolyff, Rudbeck, Bartholin, Nuck, Salzman, Hunter, Monro, Meckel, Sograf, Hewſon, and Walter, for the ſake of elucidating that ſyſtem, a double genus of veſſels hence ariſes, in regard to the liquor they convey, viz. the lacteal, originating from the inteſtines, its courſe being directed through the meſentery towards the recptacle of the chyle; the other, the lymphatic, coming from all the reſt of the body and its cells, and joined with the former in many places.

LIV. Theſe glands themſelves are, as it were, only ſmall clues [31] of lymphatic veſſels connected by a cellular texture, into which the arterial liquor exſudes, and is conveyed from the ſame by the veſſels which ſerve to bring back the lymph. They are covered with a continuous membrane almoſt of an oval ſhape; and this is the caſe, whether they are ſingle or heaped together: and they chiefly follow the courſe of the veins through the whole trunk of the body, even to the tops of the limbs; running along the jugular and ſubclavian [32] veins, the vena cava ſuperior, the aſpera arteria, gullet, lumbal vena cava, vena porta, the iliac, hypogaſtric, and crural veins, the veins of the thigh, and likewiſe the veſſels of the ſtomach, ſpleen, meſentery, and meſocolon.

LV. They are found ſeated on all the ſurfaces of the viſcera, in the thorax and abdomen; but are more eaſily diſcovered in brutes. They run through the lower part of the face, muſcles of the tongue, the adjacent parts of the neck, and thoſe parts of the upper limbs which are neareſt the trunk, as far as the bending of the elbow [33]; throughout the whole length of the mediaſtinum, before and behind, and wherever we find conglobate glandules, either in the neck or thorax: the lymphatic veins are alſo ſpread through the whole lumbal region that is contiguous to the aorta, the meſocolon and pelvis, veſſels and ſurface of the teſticle; and in the lower limbs, wherever they are ſupplied with conglobate glandules, even to the knees. Whether they extend further into other parts throughout the whole body, or through the brain, eyes, hands, feet, back, fore part of the peritonæum, &c. remains as yet undetermined; at leaſt, there are not examples enough in the human body upon which one can depend to evince the truth of their exiſtence. But they are every where to be found upon the ſurfaces of the viſcera. They are almoſt every where collected into bundles not far from the large blood-veſſels. Thoſe from the inferior limbs, pelvis, and loins, run into one duct, which is joined by another bundle coming from the liver, ſpleen, and ſtomach; and that trunk at length becomes the thoracic duct. The ſuperior veſſels, from the whole extent of the breaſt, the head, and ſuperior limbs, empty themſelves into the ſame duct towards its upper extremity. They ſeem, however, likewiſe to terminate in the red veins[34].

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[31] It is now certain, from the experiments of Hewſon and my own, that the lymphatic and lacteal glands do not, as has been imagined, conſiſt of cellular texture, as if reſembling a ſponge, into whoſe cells the other lymphatic veſſels might empty their liquors, and others again might take up the ſame; but that they are a combination, as it were, and conjunction of ſeveral lymphatic veſſels; many of which are indeed divided into leſs branches, from which larger branches ariſe: which ſtructure, however, by no means interrupts the ſeries, nor prevents the fluids from moving through the gland.

[32] New ones have been deſcribed by Camper in the interior ſurface of the ſternum, ſituated near the mammary veſſels, very neceſſary to be known for underſtanding cancers of the mammæ.

[33] As the preſence of abſorbent veſſels has been demonſtrated, both lymphatic and lacteal, in many claſſes of animals, as the birds, viz.

LVI. Of what ſervice theſe glands are to the lymphatic veſſels is not well known. In the fœtus they are

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viz. the gooſe, Indian cock; amphibia, viz. the tortoiſe; and likewiſe in fiſhes; ſo I have ſeen them in quadrupeds and man, in the hands and feet, the brain and eye. It is therefore probable, that ſcarce any part exiſts, quite devoid of them: many are found always upon the viſcera, as in the liver, ſpleen, kidneys, mammæ, lungs, ovaria, uterus, teſticles, &c. nor are they wanting in the cavities of the joints.

[34] From my own trials, at leaſt, I am certain, that the lymphatic veſſels in many places pour their contents into the neighbouring veins; for from the inguinal and lumbar plexus, I have evidently ſeen conſiderable branches ſent to the crural vein, and the vena cava itſelf, and from the thoracic duct to the azygos: but experiments ſhould be repeated, before we aſſert a thing to be univerſally fact.

are ſwelled with a milky liquor, as alſo the thymus and glandulæ renales; but it is not certain whether this juice is poured out into the cellular texture. It is rendered probable by late experiments, that ſome kind of juice is prepared in theſe glands, which is mixed with the lymph; and that a thin humour, injected into the arteries, likewiſe enters the lymphatic veſſels[35]. By age, this juice vaniſhes; and the glands themſelves, being dried up, almoſt totally diſappear. A very ſudden ſcirrhus happening to theſe glands ſeems to be the cauſe of their decay.

LVII. The *valves* of theſe pellucid veſſels (LIII.) are compoſed of two ſemicircular membranes, which give way to the fluid that goes towards the larger trunks; ſo that, by applying themſelves cloſe to the ſides of the veſſel, they leave a free light or capacity through it. But the ſame valves, if the contained liquor is preſſed back towards the ſmaller branches of the veſſel, being filled out therewith, ſwell or expand, ſo as to ſhut up the light of the canal.

CHAP. IV.

Of the Circulation *or* Motion *of the* Blood *through the Arteries and Veins.*

LVIII. THE arteries and veins, which we have hitherto deſcribed, contain either blood or lymph. The red blood, whoſe nature we ſhall explain when we come to treat of ſecretion, fills the arteries and veins commonly known, which we call *red*, or thoſe of the firſt order, and which have their origin in the heart. Theſe it ſo fills in a living perſon, that at ſome times they are very looſely and imperfectly

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[35] I have ſometimes accidentally filled conſiderable plexus of the lymphatic veſſels in the liver, lungs, and ovaria, through the arteries; but I muſt confeſs, that before this happen, the liquor ſhould be far more frequently poured out from the veſſels into the cellular texture than into the canals of the lymph. But frequently, in dropſical perſons, I have ſeen the lymphatic veſſels ſufficiently large, to equal a quill's thickneſs in a dropſical ovarium.

perfectly diſtended by it, and at other times they are rendered very full and turgid. After death, the veins are found fuller of blood than the arteries; but ſometimes, when the perſon has been dead a conſiderable time, the ſmall veins have been found diſtended with air. But the arteries of a dead body commonly contain only a ſmall quantity of blood.

LIX. This diſtending blood, then, is rapidly moved through all the veſſels of a living body. The truth of which is demonſtrated to us from wounds, by which the patient ſoon expires from the loſs of ſo much blood as was neceſſary for the maintenance of life; which loſs of blood happens almoſt inſtantly from the larger arteries, and ſometimes very ſuddenly from the ſmaller ones: but from the veins, unleſs they are ſome of the largeſt, this loſs of blood is more ſlow and difficult; yet are there not wanting inſtances of fatal hemorrhagies from wounds of the veins, in the inner corners of the eyes, and thoſe under the tongue[36]. Experiments made upon living animals ſufficiently evidence the impulſe and rapidity with which the blood is moved, particularly through the arteries[37]. In the larger trunks, it runs moſt ſwiftly; but in the leaſt of them, ſomewhat ſlower. And, in the larger veins, the blood's celerity is leſs than in the arterial trunks, in the ſame proportion as the lights or ſections of the arteries are leſs than thoſe of the veins, i. e. twice or almoſt thrice ſlower. Another argument of the circulation, is the compreſſure and relaxation of a vein, whereby the motion of the blood is promoted from one valve to another. This motion of the blood is, in the veins, uniform or equable enough; but in the arteries it is alternately greater when the veſſel is more dilated, and leſs when it is contracted. This is proved by ocular inſpection in living animals.

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[36] There are likewiſe examples of hemorrhagies from the frontal from anger, and likewiſe from the ſmall ſaphena in a gravid woman, which threatened death, in whom I tried the opening of the veins.

[37] The height to which blood from cut carotids aſcended, according to Hales's calculation, I ſaw confirmed in robuſt men who had been ſentenced to die, to wit, about ſeven feet; with this difference, however, that in two examples the blood ſprung higher from the vertebral than from the carotid veins.

LX. That the motion which the blood deſcribes, is a courſe through the ſanguineous arteries into the veins, is diſcovered from experience. For, firſt, it is certain, that all the arteries and veins communicate or open one into the other; becauſe often, from one, and that a ſmall artery, all the blood ſhall run even until death, and make all the fleſh exceedingly pale; and this not only out of the wounded limb, but from the whole body. Of ſuch fatal examples we have a number from an inner artery of the noſe, from the gums, a finger, tooth, cutaneous pore enlarged, from the lachrymal point, from the wound of cupping on the ſkin, and even the bite of a leech. There are, therefore, of courſe, open ways, by which the blood ſpeedily flows from the venous into the arterial ſyſtem.

LXI. That the blood, again, in the arteries, flows from the heart toward the extreme parts of the body, is proved by the microſcope, and by a ligature on the artery of a living animal[38]. For whatevever artery ſhall be ſtopped by a ligature, the ſwelling enſues in that part betwixt the heart and the ligature, whilſt the other part is emptied beyond the ligature, which is the part of the artery more remote from the heart: neither has it there any pulſation; nor if it be there wounded, will it yield any blood. The ſame effects, which we ſee follow from a ligature, are likewiſe often produced by diſeaſe; as when ſome tumor, by compreſſure, or an aneuriſm, intercepts the blood's motion from the heart. Experiments of this kind have been made on moſt of the arteries; anaſtomoſes, however, or the blood flowing through a neighbouring

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[38] Among the arguments which evince the real direction of the blood from the heart into the arteries, the fabric, mechaniſm, and proportion of the ſemilunar valves between each artery, and the ventricles in all quadrupeds, by no means ought to have been overlooked; for it is abſolutely hindered by them from relapſing from the arteries to the heart.

ing branch, or the retroceſſion of the blood in a dying animal, form exceptions to this rule.

LXII. But of the courſe or motion of the venous blood, it has been always more doubted; almoſt all the ancients have been perſuaded, that the blood in the veins flowed through them, either from the heart or from the liver, to all parts of the body. Very few of them have known that this was an error. Several of them have, indeed, acknowledged it to be falſe in the pulmonary vein. But that the blood did not move from the heart in the vena cava was known to ſtill fewer anatomiſts of the ancients; only to Andreas Cæſalpinus by chance, and (from an extraordinary accident) to Veſalius.

LXIII. Dr William Harvey is the firſt who experimentally aſſerted the motion of the blood returning in the veins to the heart, in ſuch a manner as to render the whole intelligible, and leave no room to doubt of it. And, firſt, *the valves of the veins* lead us to this truth: for the common uſe or office of theſe valves is, to determine the preſſure that is given from any quarter upon the veins, towards the heart, by allowing no opportunity to the venous blood that has once entered the trunk, which they intercept, to flow back to the branches. For, ſince the covering ſpaces of the valves open upwards towards the heart, the blood enters and expands them. Thus thoſe parts of the valves which project freely into the cavity of the vein, approach towards the axis, until the oppoſite ſides by meeting together ſhut up the tube. This we know from inflations, ligatures, and injections of the veins; for you never can force a liquor eaſily into the veins by propelling it againſt their valves. They do not, indeed, every where ſhut up the whole cavity of the veins; but where they ſhut not cloſe, they always intercept the greateſt part of the light.

LXIV. Another office of the valves in the veins ſeems to be for ſuſtaining the weight of the blood, that its upper columns may not gravitate upon the lower; nor the blood, flowing through the trunks, make too great a reſiſtance againſt that which follows it through the branches. For if, from the ſlower motion of the blood, its weight or preſſure ſhall, in any part, much exceed the impulſe that drives it on, ſo as to cauſe ſome part of the column to deſcend by its weight; it is, in that caſe, immediately catched, and ſuſtained in its relapſe by the next adjacent valve, which hinders it from urging againſt the next ſucceeding column, and affords time and opportunity for ſome contiguous muſcle, by its preſſure or concuſſion to propel the ſaid column. And this is the reaſon why valves are placed in the veins of the limbs and neck; in which parts they are both more numerous and more robuſt than elſewhere. And this is the cauſe of varices, when the blood, entering the hollow valves, urges their ſolid convexity downwards, and makes the vein dilate in that part. Likewiſe, in muſcular action, the valves are the cauſe of the whole effect of the preſſure which the veins ſuſtain, forwarding the blood in its due courſe towards the heart.

LXV. Moreover, the valves, placed in the right ventricle *of the heart*, have ſuch a fabric, as we ſhall hereafter ſee, that they freely permit blood, air, or wax, to paſs from the venous trunks of the cava into the heart, but deny any reflux from the heart into the veins.

LXVI. Again, *ligatures*, in a living perſon, may make the thing more evident. When the veins of the limbs are tied, either by deſign or accident, with the limb itſelf about the hams, arms, ancles, or wriſts, the limb below the ligature ſwells, the veins fill and diſtend themſelves, and when opened make a free diſcharge of blood: but at the ſame time nothing of this kind happens above the ligature, nor are any of the veins to be ſeen there. The ſame phenomenon happens when the veins are compreſſed by ſwelled and ſcirrhous glandules in the viſcera; and from polypuſes the veins are often greatly ſwelled or enlarged into tumors. Theſe ligatures will ſerve to keep the blood in any limb round which they are tied, that it may not return to the heart and be loſt through a wound in another part.

LXVII. The experiments to prove this courſe of the blood, which have been made in living animals, are ſtill more accurate. From them, even from our own, it appears, that by tying any vein, in a living animal, near the cava, or belonging to the pulmonary veins, that part always ſwells which is moſt remote from the heart, all below the ligature appearing diſtended with the retained blood, while above and next the heart they are pale and flaccid. Laſtly, if the arteries are tied at the ſame time with the veins, theſe laſt remain flaccid and empty; but, upon removing the ligature from the arteries, the veins are immediately filled.

LXVIII. In like manner, the infuſion of poiſons or medicinal liquors ſhow, that, into whatever vein you inject chemical acid ſpirits, the blood is driven along with the force of the poiſon to the heart itſelf. But when, from this cauſe, the brain is affected with the narcotic virtue of opium, and the inteſtines and ſtomach with the virtue of purgatives and emetics, this is a demonſtration that the blood, with which theſe ſubſtances were mixed, had paſſed through the ramifications of the veins to the heart, and from thence thro' the whole body.

LXIX. Another proof we have in the *transfuſions* of blood; in which all the blood from the arteries of one animal is urged into the veins of another exhauſted of blood; whereby the heart, arteries, and empty veins of the latter become ſo turgid and well repleniſhed, that they work the whole machine of the animal with a remarkable degree of vivacity, or even cauſe it to labour under a plethora.

LXX. But that the blood paſſes from the leaſt arteries into the leaſt veins, we are clearly taught by *anatomical injection;* where, by one arterial trunk, we eaſily fill all the arteries and veins, almoſt throughout the whole body; provided the liquor be watery or very fluid, ſo as to paſs eaſily in the veſſels of the head, meſentery, heart, and lungs.

LXXI. Laſtly, *the microſcope* has put the matter beyond all doubt in the pellucid tails, feet, and meſenteries, of animals; where we ſee that the blood, brought to the extreme parts by the arteries, is poured either into ſmall veins, continuous with the reflexed artery, or elſe goes through branches of the arterial trunk into the parallel communicating vein, by which it goes on to the parts neareſt the heart. This is the way in which the blood paſſes as well into the leaſt veins which are capable of receiving only one globule, as into thoſe that are ſomewhat larger, being able to admit two or more globules to advance forward in a breaſt. But that there is no ſpongy or parenchymous interpoſition betwixt the arteries and veins, in the general courſe of the circulation, is proved both from microſcopes and injections. For if there were any ſuch parenchyma or ſpongy maſs betwixt the arteries and veins, the hardening injections would ſhow it, by appearing extravaſated in a like unſhapen maſs.

LXXII. The circulation of the blood is, therefore, now received by every one as a medical truth; namely, that all the blood of the human body is carried through the aorta, from the left cavity of the heart, to the extreme parts or converging ends of the arterial branches; from whence the whole maſs is again tranſmitted into the leaſt veins, which convey it to the larger, and from them into the cava and heart itſelf; in which courſe it perpetually goes and returns during life.

LXXIII. Yet there are ſome inſtances where, by paſſions of the mind, a ſudden revulſion by copious blood-letting, or convulſions, the blood has been forced to recede back from the ſmaller into the larger arteries; and, on the other ſide, where an obſtruction being formed above the valves, the blood has been known to ſlide back from the venous trunks into their ſmaller branches. But then theſe accidents are very momentaneous or ſudden, and the blood ſoon returns into its natural courſe. Theſe things happen moſt frequently in the abdomen and vena portarum.

LXXIV. The courſe of the humours *in the lymphatic veins* which have valves, appears both from the nature of thoſe veins, and from ligatures: for every lymphatic vein tied ſwells betwixt the ſmaller extremities of it and the thoracic duct; but grows flaccid betwixt the ſaid duct and the ligature. All the valves in theſe, like thoſe of the blood-veins, give a free paſſage for flatus and mercury to flow to the thoracic duct: but they make a reſiſtance, and often an obſtinate one, to any return the other way; although ſometimes they have been known to yield[39].

LXXV. *The vapours* that moiſten the whole cellular ſubſtance, the ſteams of the abdomen and other venters, are all thus drunk up by the leaſt pellucid veins, and ſo conveyed to the blood-veins, that their contained juices may paſs on to the heart: and from thence it is, that œdema enſues, when a vein is compreſſed by a ligature; becauſe by intercepting the courſe of the abſorbing veins by the ligature, the vapours ſtagnate unabſorbed. In the other ſmaller veſſels, we can make no experiments: but they appear conformable to what we have ſaid, both from reaſon and analogy; and are likewiſe ſupported by the experiments of water or other liquors, abſorbed out of the cavity of the inteſtines, thorax, and pulmonary veſicles.

LXXVI. All juices, therefore, in the human body, are drove out of the heart into the aorta; from whence they are all returned again to the heart by the leaſt veins;

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[39] I have ſometimes found that they admit a fluid in a contrary direction, when I was puſhing air through the lymphatic veſſels of a dropſical ovarium into the leſſer plexuſes, and mercury from the thoracic duct into ſeveral lacteal veſſels of the meſentery, and the lymphatics of the loins and pelvis; it goes backwards alſo in the hepatic plexuſes: but I confeſs I never ſucceeded in the joints.

veins; thoſe humours only excepted, which are exhaled or diſcharged withoutſide the cavities of the body. To complete this circle, it only remains for us to find out a courſe for the blood, from the right to the left cavities of the heart: but then this ſuppoſes us to be firſt acquainted with the hiſtory of the heart, and the pulmonary veſſels.

CHAP. V.

Of the HEART.

LXXVII. THE fabric of the *thorax*, compoſed of bones and cartilages in general, reſembles a truncated cone, as we ſhall afterwards remark. The lateral parts of this cone are two membranous bags, terminated above by an obtuſe end at the firſt rib, where they lie very near together, and are diſtinguiſhed by the interpoſed cellular ſubſtance only. The obliquity of the plane, dividing theſe two bags, is ſuch, that the right is much the broadeſt, and adheres in its deſcent all along to the whole middle of the ſternum; but, in its deſcent, is inclined to the left ſide, and comes from the margin of the ſternum itſelf; while the left bag deſcends, not from the ſternum, but from the cartilaginous ends of the ribs. The inner central ſides of theſe bags, oppoſed one againſt the other, make up what anatomiſts call the *mediaſtinum*. Theſe bags have no where any communication one with the other; ſo that the right may be opened, and the lungs therein may be deſtroyed, without injuring the left. But the ſimple denſe membrane, which forms theſe bags outwardly inveſted with the cellular ſubſtance, is called the *pleura;* being harder than the peritonæum, eſpecially where it adheres to the back; but is ſomewhat ſofter in its fore part, and is almoſt deſtitute of feeling[40]. The capacity of the mediaſtinum, or that interval which lies betwixt the right and left bag, broadeſt above, and likewiſe below, contains the thymus, and ſome conglobate glandules, fat, and veſſels, and, in ſome diſeaſes, pus.

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[40] It indeed wants that degree of ſenſibility which other parts ſhow that are furniſhed with more nerves; but whether the pleura,

LXXVIII. Below, the ſame bags, growing broader, depart one from the other, and leave a capacity thro' the whole middle part of their extent, by which the ſaid bags are divided one from the other. And this capacity is that of the pericardium. But the bags of the pleura on each ſide of the pericardium, deſcending both before and behind it, terminate finally on the diaphragm, about the fifth or ſixth rib; and on this their baſe is cut off obliquely, ſo that each cavity is before ſhorter in the fore part, as behind they deſcend longer and lower, in ſuch a manner as to be hollow in the upper part. Theſe bags contain the lungs. The back parts likewiſe of theſe bags are more tender; and though they lie near to each other, are yet ſeparated by the cellular ſubſtance which terminates in the pericardium, and includes the aorta, together with the œſophagus; and this we call the *poſterior mediaſtinum.* The triangular productions of the ſides of the mediaſtinum form the ligaments of both lobes of the lungs.

LXXIX. The *pericardium*, or third bag, which firſt the cellular ſubſtance, and then the conjoined pleura, looſely cover on all ſides as an outer coat, touches the ſternum indeed but by a very ſmall part; ſince the lungs, when diſtended, cover the heart almoſt wholly before, and interpoſe betwixt the ſternum and pericardium in their lower part; and the mediaſtinum, gradually diverging towards the left ſide, forms quite a narrow interval under the lower end of the thymus, cloſe to which the lungs meet on each ſide: but this ſituation you will derange, unleſs you are very careful in your manner of opening the thorax

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pleura, in proportion to its want of nerves, is perfectly deſtitute of the feeling power, we ſhall, when opportunity offers, make farther inquiry (CCCLXV).

thorax. The pericardium has a broad, but ſomewhat round, baſis, adhering to the tendinous part of the diaphragm, and by a ſmall part to the fleſhy ſubſtance of the ſeptum on the left ſide about the fifth or ſixth rib. In young ſubjects it adheres more laxly; but in adults very firmly, by the cellular ſubſtance ſpreading broader to the right and narrower towards the left. It is ſomewhat larger than the heart; which, therefore, may move freely therein. This membranous capſule or fence of the heart, was never known to be abſent [41].

LXXX. Upwards the pericardium grows gradually narrower, ending above the heart in an obtuſe conical appendix, extended over the coats of the large blood-veſſels almoſt to the upper edge of the ſternum. It adheres firſt to the inferior branch of the right ſuperior pulmonary vein; then to the vena cava; after that to the aorta, on its acceſſion to which it riſes higher up; then it adheres to the deſcending trunk of the ſame veſſel, and to the ductus arterioſus; from hence it is ſpread upon the left branch of the pulmonary artery; then on both branches of the left ſuperior pulmonary vein. On the back part it is again attached to the right pulmonary vein; then to the left ſinus, to both pulmonary veins on the left ſide, and to the auricle of the ſame ſide; from thence it proceeds a long way from the pulmonary vein even to the inferior cava, then to the ſeptum of the ſinuſes, then to the inferior cava. Beſides, it goes to the pulmonary artery, its right branch, and the aorta under the origin of the large branches, in ſuch a manner as to ſurround both arteries with a cylindrical production of its ſubſtance, whence it appears like a kind of partition between every two neighbouring veſſels. Thus alſo it contains the vena cava ſuperior as in a ring, the anterior and poſterior cavities of the pericardium being freely continued between that vein and the aorta. In like manner it ſurrounds the inferior cava. But this ſheath, by which the veſſels are ſurrounded, preſerves its nature only for a ſhort ſpace, and immediately returns to the heart with thoſe large veſſels to which it ſerved as an external coat. It alſo ſends a cellular fabric like a ſheath, along with the great arteries and veins, to the lungs[42].

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[41] Nor is it really wanting in ſome quadrupeds, as the hedgehog, to which it has been refuſed, but only more tightly tied to the heart.

LXXXI. The *arteries* of the pericardium are either from thoſe of the thymus, which accompany the upper and lower phrenic nerves, or from the larger phrenic arteries, from the branches of the mammaries and mediaſtinals, the bronchial, œſophagal, and poſterior mediaſtinal arteries, or from the coronaries which inoſculate with the bronchials and others. The *venous trunks* of the pericardium have a like origination, but appear with moſt evident anaſtomoſes from thoſe of the right into the others of the left ſide. The *nerves* of the pericardium are from the ſuperficial branches of the cardiacs.

LXXXII. That which makes the proper ſubſtance of the pericardium, is a ſtrong, white, compact membrane, more robuſt than the aorta itſelf, through which the nerves of the heart and ſome ſmall veſſels deſcend. Its outer ſurface being ſpread with the cellular ſubſtance, gives it there a ſomewhat rough appearance, while internally it appears highly poliſhed, and moiſtened on all ſides by a watery vapour. This vapour, which we have, times without number, obſerved in the living animal, compoſes ſome, though naturally a very ſmall quantity, of a water within the pericardium; which is either limpid, yellowiſh, or reddiſh, and ſubviſcid or gelatinous; by diſeaſe, it is ſometimes increaſed to an immenſe quantity; yet the exiſtence of ſuch a water here is injudiciouſly denied by ſome. The *water* of the pericardium is of a lymphatic nature; becauſe by heat it hardens into a jelly; and from hence ſmall fibres and a cellular ſubſtance are often found, in ſome diſeaſes, mixed with the natural viſcous humour which every where exſudes from the heart and its pericardium. This liquor is ſeparated without any intermediate glandules, or any viſible pores, from the ſmall exhaling arteries of the heart, auricles, and pericardium; as may be proved by a ſimilar tranſudation of water or fiſh-glue injected into the large arteries.

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[42] It is more rare, and belongs only to varieties, when appendices are found in the pericardium; ſuch as I have ſeen ſent to the under lobe of the lungs of the left ſide, an inch long, and even more.

LXXXIII. The *uſe* of the pericardium is to contain the heart along with this vapour; and to ſupport and ſtrengthen it as a fulcrum or prop, that, in contraction, the fibres of the heart may be drawn together without diſtorting the large blood-veſſels, and that by its vibration may not be ſenſible of altering the poſition of the bōdy. For theſe reaſons we find it in all animals that have a true heart. A watery vapour here bedews the heart, which is hotter and quicker moved than other parts, ſo as to hinder attrition and coheſion betwixt it and the pericardium; but when this vapour is dried up, or deficient, the pericardium adheres either to ſome one part only of the heart, or to its whole ſurface, ſo that it ſometimes ſeems to be entirely wanting.

LXXXIV. Nature hath given a heart to moſt animals[43], even to many inſects and worms: to others ſhe hath denied it; and theſe are the moſt ſimple of all animals, even very large ones, though they are irritable throughout their whole body; as, for inſtance, he prickly hydra. Thoſe animals who have no hearts, have alſo no veſſels.

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[43] The heart, with reſpect to the cavities, and the veſſels which correſpond with theſe cavities, may, in the more perfect animals, be divided into two claſſes. For thoſe animals which have no real lungs to complete reſpiration and circulation, are furniſhed only with a bilocular heart, one ſinus which receives the blood, and one ventricle which ſends out an artery; as in fiſhes, and almoſt al amphibia. But a quadrilocular heart is always an attendant upon real lungs, receiving a great part of the blood, and it is obſerved to be formed of two ſinuſes, with as many correſponding veins, and of two ventricles ſending out two arteries; as in quadrupeds, birds, cetacea, if we credit Raius.

LXXXV. The veins which carry back the blood from the whole body to the heart, if we except thoſe of the lungs, are reducible to two[44]. The *càva* is improperly named in the ſingular by anatomiſts, ſince it is no where, or for a very ſhort ſpace, one ſingle trunk. The lower of the two large veins, which is the biggeſt of them in man, aſcends immediately above the diaphragm from the right ſide, towards which it is a little convex or gibbous, to its union with the upper cava; and, together with that in its back part, forms a middle partition betwixt the right and left ſinus: but the left ſide of the venous tube degenerates into the right auricle, whoſe fibres are a continuation from thoſe of the cava. What we have here ſaid of the lower cava is alſo true of the upper.

LXXXVI. Thus by the meeting of the upper and lower cava, a ſinus or cavity is formed with a convexity to the right, and inwardly filled with ſtrong, fleſhy fibres, detached betwixt the two ſimple membranes, and variouſly interwoven. But the ſame cavity, to the left and fore part, dilates forwards into an almoſt perpendicularly oblong or oval form, and terminates above with a blind-pointed end, which is free from adheſion with the heart, and lies incumbent on the great artery. This cavity alſo, like the former, has plenty of fleſhy fibres placed betwixt two very thin membranes, almoſt in a parallel poſition; and theſe form a kind of arch, extended from the right to the left edge of the whole cavity, and round the anterior half cylinder of this cavity; and theſe muſcular arches are connected together by ſome of the leaſt fibres. This anterior part of the cavity is called the *auricle;*

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[44] Theſe are very rarely found, when all the veins of the left ſide of the head, the neck, arm, and thorax, have run into one common trunk, which is directed to the ſinus of the venæ cavæ.

ricle; but that to the right and poſterior part is called the *ſinus*[45]*:* it is thin at the partition of the auricles, and likewiſe between the oval ring and where the vena cava enters the heart. In this appendix there ſeem to be three large muſcles, the anterior, poſterior, and inferior.

LXXXVII. In the partition which ſeparates the two auricles, the baſis lying in the middle between the two venæ cavæ is depreſſed to the left ſide, more on the upper and leſs on the under part; and, at its baſis, the partition is exceedingly thin. I ſhall call it the *oval foſſa.* It is bounded on both ſides by a fleſhy column, by the union of which an arch is formed at top, while the thinner parts at bottom are turned backwards to meet one another. This I call the *oval ring;* others, the *iſthmus.*

LXXXVIII. Where the lower cava opens into the right auricle[46], from the tumid column of the left ſide of the foramen ovale ariſes a moon-like membrane, naturally complete in its figure, and from its thinneſs in adults ſometimes net-like: and this being extended round the lower edge of the auricle, grows thinner all the way, as it is incurvated to the right; but does not quite ſurround half of the auricular circumference, the cavity of which it ſerves like a partition to divide from the vena cava. This is called *Euſtachius's valve.* The oval foramen we ſhall deſcribe hereafter.

LXXXIX. The blood of the two venæ cavæ is propelled by a muſcular force, in either vein, into this *atrium* or porch of the heart, compoſed of the ſinus and auricle. Theſe veins, as far as they lie within the breaſt, are endowed with ſtrong and irritable muſcular fibres, by whoſe contraction the blood is driven into the neighbouring auricle.

XC. In like manner, the auricle, being irritated, is contracted on all ſides. And, firſt, by a conſtriction of its muſcular fibres, the anterior ſemicylinder of the auricle is reduced to a plane; while the ſame fibres, by their contraction, bring back the middle arch towards the anterior extremity or beginning of the heart, and likewiſe towards its poſterior extremity or ſinus. Then the appendix to the auricle deſcends, and is contracted tranſverſely by itſelf, while the lower part aſcends; and thus the auricle becomes ſhorter. Again, the left edge turns evidently to the right, and the right edge a little to the left; and thus the auricle is rendered narrower. Thus the blood of both cavæ, being mixed together in the beginning of the heart now diſencumbered, is driven through the edges of the open valve, in ſuch a manner as to urge the valves of the right ventricle cloſe to the ſides of the heart. But the blood is now hindered from returning again into the lower cava, both by the contraction of the auricle, the reſiſtance of the ſucceeding blood from the abdomen, and of the *Euſtachian valve;* and upwards it is hindered from aſcending, both by the motion and weight of the conſequent blood. It is driven back, however, on both ſides, if there happens to be any obſtacle in the lungs.

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[45] The ſinus of the venæ cavæ is a very proper name, as the ancient names of right and anterior are very ambiguous.

[46] Or, according to Wolfe's opinion, it opens into each ſinus in the fœtus.

XCI. The *figure of the heart* itſelf, in ſome meaſure, reſembles half a cone, if the cone be ſplit into two longitudinally in the direction of is axis. It is almoſt triangular; only the end of it is obtuſe, and the lower ſide of it is flattened in proportion to the diaphragm on which it lies incumbent, and is thereby ſuſtained. But the convex ſurface of the cone is ſo inclined within the pericardium, under the great blood-veſſels, as ſuffices to place its thicker ſemicircular curvature, which modern anatomiſts call its *obtuſe margin*, directed to the upper and to the left ſide of the breaſt: in its lower and anterior part, the heart is alſo extenuated into a kind of edge, which is called its *acute margin;* but the point is turned a little forwards. This is the general ſituation of it in mankind; but in brutes, the heart being almoſt parallel to the larger axis of the thorax, its apex or tips only extend to touch the diaphragm.

XCII. The whole heart is hollow, having its *anterior*, formerly called its *right ventricle*, communicating into the right auricle and ſinus[47], which is broad and ſhaped like the fourth part of a cone; not ſo long as the poſterior left ventricle, but larger; and it terminates in the ſhorter tip of the bifurcated apex of the heart. The mouth of this ventricle, where it opens into the auricle, is elliptical; and terminated by a white glutinous margin, more callous than tendinous: over this, plates of muſcular fibres are ſpread, and ſome fat lies outwardly upon theſe.

XCIII. From this callous margin is extended, within the heart, a membranous ring, formed by a reduplication of the internal membrane of the auricle, extended ſo as to float within the ventricle to which it was before continuous. But this ſame ring, in that part which fluctuates in the ventricle, is ſo ſplit or divided into three unequal triangular portions, that you may in ſome meaſure give them the name of valves, and count three of them in number, although they are in fact only continued parts from one broader ring. Theſe were, by the ancients, named *triglochines*, or *valvulæ tricuſpidales*[48].

XCIV. That part of theſe valves which lies next to the ſides of the heart is ſtrengthened by tendinous fibres, which, meeting together in their courſe, are inſerted by very ſtrong cords, partly into the ſides of the heart, and partly into papillary or cylindrical muſcles, which ariſe upward from the left ſide of the right ventricle towards its right ſide. The largeſt of theſe muſcular columns is that which anſwers to the biggeſt of the valves, which is both the uppermoſt and that which anſwers to the adjacent mouth of the pulmonary artery. The leaſt of them is the loweſt, and is ſituated before the acute margin.

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[47] I call it the *ventriculus pulmonaris*, ſince it alone conveys the blood into the lungs, and is wanting in animals which draw in a great deal of blood.

[48] It is a better name, *valvulæ venoſæ ventriculi pulmonaris*, as it pointedly marks the courſe of the venous blood.

XCV. The uſefulneſs of this valve is evident enough; for the right auricle (XC.) being contracted, the blood contained in the right porch of the heart, at the looſe extremity of the auricle, being impelled from the circumference towards the axis, like a wedge, ſeparates the pendulous portions of the ring, called *tricuſpid valves*, and preſſes them to the ſides of the heart. Thus is filled the right ventricle of the heart, while the uppermoſt valve (XCIV.) ſhuts the pulmonary artery, leſt the blood, by the weak impulſe of the auricle, ſhould flow into that artery: the blood thus received, and confined within the right ventricle of the heart, is, by the ſtrong contraction thereof, more powerfully expelled into the artery.

XCVI. The ſenſible fleſh of the heart, being irritated by the quantity and weight of this warm blood, is thereby ſolicited to a contraction: for that the heart, being irritated, will contract itſelf in a perſon dying, or even lately dead, is proved by injections of water, and inflations of air, whereby the heart, then quieſcent, is recalled to its motion.

XCVII. The heart's motion is performed by *muſcular fibres;* the originations of which, in general, are from rings formed of the cellular ſubſtance, compacted into a callous ligament, agreeable to the deſcription given in XCII. and with which all the larger blood-veſſels at their opening into the heart are ſurrounded. From thence the fibres, which ariſe, deſcend gradually in an oblique winding courſe towards the left ſide, and forward to the apex, in many diſtinct plates, and ſometimes a little traverſing each other, the middle ones being the moſt tranſverſe, while the outermoſt and innermoſt deſcend in a ſtraighter line. In the flat ſide of the heart (XCI.) there are few fibres; and ſo thin, that when you have removed the fat, the cavity appears almoſt uncovered. That which is called the left ventricle, is, however, very firmly inveſted by the fibres; which, after ſurrounding the ſame ventricle, form a ſlight decuſſation in the ſeptum cordis with the fibres of the right ventricle, and are interwoven with them. Some of theſe fibres deſcend into the cavities of the ventricles, and form there the fleſhy columns mentioned at XCIV. Others at the tip of the heart, are wound in a vortical or whirling poſition, the two horns ending by a ſtrong faſciculus or bunch in each ventricle. A very thin and ſmooth membrane covers the external and internal ſurface of theſe fibres; but the external membrane, eſpecially where it is ſpread over the coronary veſſels, contains much fat beneath it. I have, for my own part, not been able to diſtinguiſh any thing more particular in the muſcular fabric of the heart, with any tolerable degree of evidence; becauſe it is the peculiar property of the fibres in the heart to join together in branchy appendices or heaps, in ſo ſtrict union, that they cannot be ſeparated without laceration.

XCVIII. But there are ſeveral eminent anatomiſts, whoſe ingenuity and communicative freedom I reſpect, who have repreſented and deſcribed thoſe fibres diſplayed and ſeparated: namely, the external fibres of the heart, common to both ventricles, deſcending to the tip, and then, taking another courſe, to inſert themſelves into the ſeptum; others again, at the tip, to perforate the left ventricle, and return, in a contrary courſe, to the baſis along the inner ſurface of the ſaid ventricle. But the middle fibres, betwixt the aforeſaid inner and outermoſt ones, being variouſly inclined towards the baſis, form the ſeptum. And others have given us figures and deſcriptions of ſtill different orders of fibres, of which the outermoſt run counter to the innermoſt, while the intermediate are tranſverſe. To which deſcriptions, as they are not much different from my own obſervations, I ſhall make no oppoſition, although I have never been able to ſee this diſpoſition of them ſufficiently manifeſt, and am acquainted with great anatomiſts who have not been more ſucceſsful than myſelf.

XCIX. Theſe fibres of the heart, like other muſcles, are furniſhed with *nerves* of their own, very numerous and of various origin. The firſt and uppermoſt are on the left ſide [49] from the ganglion of the intercoſtal with the uppermoſt cervical nerve. With theſe are joined others from the pharyngeal plexus of ſoft nerves; others, produced from the pharyngeal and gloſſo-pharyngeal ganglions, are mixed with them; others alſo are added from the trunk of the intercoſtal nerves; and others from the middle ganglion ſeated on the ſtraight muſcle about the paſſage of the thyroid artery, which has branches both from that uppermoſt nerve and from the trunk of the intercoſtal and phrenic nerves. Others come from the recurrent nerve of the eighth pair. The nerves of the heart, originating from theſe ſources, (wove together into a plexus, partly before the great artery, in which the following ones are mixed together; and partly forming ſeveral ſmall plexuſes between the aſpera arteria and the large arteries going out of the heart), form one or more plexuſes out of the nerves of the right and left ſide; which plexuſes are commonly joined together, though ſometimes they are diſtinct. From this ſame plexus, or plexuſes, other

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[49] Upon comparing my own obſervations with Anderſch's and Neubaver's deſcription of the cardiac nerves, I ſee that the riſe on each ſide, courſe, and manifold intermixture of the cardiac nerves, if you except the deeper deſcent of the eighth pair of the left ſide into the thorax, and the more remote origin of the recurrens ariſing from thence, are very ſimilar; ſo that I have nothing to add: But among the cardiac branches I found a greater one in ſeveral ſubjects; of which, as it is not ſufficiently underſtood, I ſhall add a deſcription. From the great cardiac plexus, which the uſual filaments form, five or ſix ſmall nerves, forming a net-work, at length run together into one trunk, a little leſs than the recurrent: while it deſcends into the ſoft cellular ſubſtance, cloſe to the aſpera arteria, it runs with the various furrows of the plexus pulmonaris out of the eighth pair; then it is divided between the aorta and pulmonary artery into two branches, and ends partly in theſe arteries and partly in the right ſide of the heart.

nervous twigs paſs betwixt the aorta and pulmonary artery to the right artery of the heart; others croſs the pulmonary artery, and go betwixt it and the left auricle to the coronary artery of the ſame ſide; others behind the pulmonary artery to the ſame coronary; and others, again, deſcend very deeply behind the pulmonary artery to the left ſinus and flat ſurface of the heart. To the cardiac plexus, above deſcribed, other large nerves accede from the fifth and lower cervicals, and ſometimes from the phrenic nerve, and from a ganglion of the loweſt cervical with the intercoſtal, to which join large roots from the loweſt cervical nerves. The laſt deſcribed nerves, which are larger, ſofter, and more tranſverſely diſpoſed, are partly mixed with the foregoing plexus, and partly go to the lungs. Laſtly, there are ſome ſmall branches, uncertain as to courſe and number, which join the cardiac plexus from the recurrent and eighth pair of nerves; and making various inoſculations with the intercoſtals, are confounded with thoſe of the eighth pair. As for thoſe nerves, which ſome eminent anatomiſts have ſeen aſcending from the great abdominal plexus to the heart, through the foramen of the vena cava, I have never been able to find ſuch; although it is eaſy enough to diſcover the diaphragmatics in that place, having ganglions peculiar to themſelves, of which thoſe anatomiſts make no mention.

C. That theſe nerves conduce powerfully to move the heart, is the opinion of eminent anatomiſts, from a conſideration of the common nature of muſcles; and from the increaſe which follows in the heart's motion, by irritating the eighth pair of nerves, either at the brain or the ſpinal medulla; and from the languor that enſues upon tying thoſe nerves, which proves fatal, either ſuddenly or within a few days, even though you happen to make the ligature on but a few of the nerves that come to the heart; for the intercoſtal, and eſpecially thoſe from the ganglion of the upper thoracic, cannot be tied.

CI. But that there are ſtill other cauſes, beſides that of the nerves, conducing to the motion of the heart, we are perſuaded from obſerving its motion undiſturbed by the irritation of all the nerves in the living animal; from its remaining after the greateſt wounds of the head, and even of the cerebellum and medulla ſpinalis; likewiſe from its motion when torn out of the breaſt; chiefly in thoſe animals whoſe lungs, being impermeable, make no reſiſtance to the heart's motion; for the motion of the heart is obſerved to be very vigorous in the fœtus before the brain is well formed, and likewiſe in animals wanting the head. And all our experiments agree in this, that the quieſcent heart in dead or dying animals, when irritated by heat, vapours, poiſons, and eſpecially impelled flatus, watery liquors, wax, or blood, or on receiving an electric ſpark, immediately contracts itſelf, putting all its fibres into a rapid motion, by a force ſometimes common throughout the whole heart, and ſometimes affecting only a particular part of it.

CII. Thus then we ſee, that there reſides in the heart a kind of impatience of ſtimulus; ſo that even in the viſcus, when almoſt dead, wrinkles, and motions of different kinds, appear to be propagated along its ſurface, from places as it were irradiating from points: again, the heart, when torn out and cold, on being pricked, inflated, or irritated, contracts itſelf; and its fibres, when diſſected, corrugate themſelves orbicularly, when there is neither nerve nor artery to bring it ſupplies of any kind. This irritability is greater, and remains longer in the heart, than in any other part of the body; ſeeing, by ſtimulating it, the motion of the heart may be renewed at a time, when that of no other muſcle can. The heart of the fœtus is moſt irritable, as well as larger, in proportion, than in adults; and moſt tenacious of its motion, even in the cold. That motion is *peculiar to the heart itſelf*; coming neither from the brain, nor the ſoul; ſeeing it remains in a dead animal even when the heart is torn out of the breaſt; neither can it, by any act of the will, be made either quicker or ſlower.

CIII. It is, therefore, evident, that the ſtimulus, occaſioned by the impulſe of the venous blood, cauſes the heart contract itſelf; and that this contraction is convulſive, made with great celerity, and a manifeſt corrugation of the fibres; whereby the whole heart becomes ſhorter, thicker, and harder; ſo that the left ventricle is drawn ſomewhat towards the ſeptum of the heart, and the right one much more. The baſe alſo advances towards the apex; but the apex more evidently towards the baſis. This I have often obſerved with the greateſt certainty in diſſecting brute animals; ſo that thoſe learned gentlemen muſt have ſome way or other been deceived, who have aſſerted, that the heart is elongated during its contraction. But the heart does not ſeem to turn pale in ſuch animals as have warm blood. Even the ſeptum of the heart is rendered ſhorter, and draws itſelf towards the baſis. By this action, the fleſhy parts of the heart ſwell inwardly, and compreſs the blood as they do the finger, when introduced into its cavities. But that the heart is accurately enough emptied in this action, appears from the event; the evident paleneſs of animals whoſe heart is white, as frogs and chickens; and from the internal ſurface being full of eminences, which exactly anſwer to oppoſite cavities, and to the thick reticular arms or columns interrupted by ſinuſes. And beſides, the apex of the heart, being contracted a little like a hook, ſtrikes againſt that part of the pericardium next the thorax. Forwards, there is alſo a pulſation from the left venal ſinus; which is at that time particularly filled. In exſpiration, the heart ſtrikes violently upwards and forwards. The truth of both theſe we know by experiment.

CIV. The blood, which is preſſed by the contracted heart (CIII), endeavours to eſcape in all directions; but being driven from the muſcular ſides, towards the axis of the ventricle, by the reaction of what is lodged betwixt the venal ring (XCIII.) and ſides of the heart, the looſer ends of the ſaid ring are driven forwards and extended inward at the ſame time. By this action upon the whole circumference of the ring, it not only becomes extended itſelf, but, at the ſame time, rejects a part of that blood into the right auricle, which had before deſcended into the cone of the open valve, whoſe ſides, now approaching, ſhut up the venous orifice more cloſely as the heart contracts more ſtrongly; by whoſe force the tricuſpid valves as they are called, would be preſſed reduplicated into the auricle, if the muſcular nipples (XCIV.) or columns did not keep down their edges, and hold them firmly by their contraction (which is the ſame with that of the heart) in ſuch a ſhape as will extend the annexed chords of the valve, without injuring them.

CV. But the niſus of the remaining blood, now reſiſted by the tricuſpids, ſeeks another courſe; and, whilſt the larger of thoſe valves that is ſeated to the right (XCIV.), advances from the ſide towards the axis of the heart, this leaves open the mouth of the pulmonary artery, which it before covered; whereupon the blood preſſing the valves in the mouth of the ſaid artery cloſe to its ſides thus ruſhes into it.

CVI. To deſcribe this more particularly; from the upper and poſterior part of the right ventricle, a way leads into the *artery*, taken in, as it were, between the fleſhy parts of the heart produced, and ſtrongly connected to it by a cellular callous ring, from whence the artery aſcends to the left backward, and diſplays itſelf behind the arch of the aorta. The ſtrength of this artery is not extraordinary, being much weaker than that of the aorta. But from the inner ſurface of the artery, where it is joined to the heart, *three ſemilunar valves* ariſe, by a reduplication of the arterial membranes extended upwards, and towards the axis, in an arch that is flat or obtuſe enough; and theſe valves always fluctuate with their edges at free liberty in a parabolical ſhape. The middle of the edges, in each of theſe valves, is generally divided, ſometimes in the fœtus itſelf, by a ſmall, denſe, callous body, of a conical ſhape, but made up of inclined planes; whereby each whole valve, in itſelf reſembling an half-moon, is thereby again ſubdivided into two leſs half-moons. Betwixt the two membranes of the valve, appear ſome muſcular or tendinous fibres, partly in a tranſverſe poſition; ſome of which hold faſt the valve to the next contiguous ſide of the heart, leaving ſometimes ſpaces betwixt them in a reticular manner. Other fibres aſcend from the baſis of the valve; and, by growing to the callous corpuſcle, draw back the ſaid valve, and open the ſinus.

CVII. Each of theſe valves, in conjunction with the ſides of the artery here diverging, intercept a ſpace, which is blind or impervious downward; but open upward in a parabolical ſhape, as we obſerved of the valves in the veins (XLIX.) When, therefore, the blood is impelled from the ſides towards the axis of the contracting heart, it endeavours to eſcape in the direction of the ſaid axis; and, by ruſhing forth like a wedge, betwixt the valves, preſſes their looſe ſail-like edges againſt the ſides of the pulmonary artery, ſo as to run freely out of the heart. The truth of this appears from the fabric, from injections, and from ligatures, which, by obſtructing the lungs, will not ſuffer the large cavities in the right ſide of the heart to be emptied.

CVIII. The blood now received into the pulmonary artery, goes on then to make its circulation through the lungs. That artery is firſt divided into two branches; of which the left, being leſs and ſhorter, enters directly into the ſubſtance of the lungs: but the right branch, being larger and longer, paſſes tranſverſely through the arch of the aorta; and, after going a little way behind the ſaid aorta, enters the correſponding lungs of the ſame ſide. From each of theſe branches, by a multiplied ſubdiviſion, ariſe the very leaſt arteries, ſome of which tranſmit the blood directly into the continued ſmall veins, and others exhale part of its aqueous juices into the pulmonary cells. That the blood goes thus directly from the arteries into the pulmonary veins, appears evidently from their ſtructure; alſo from a ligature, which, intercepting the blood's courſe, while the heart and lungs ſtill urge it, cauſes an aneuriſmatic dilatation of the artery; and from polypuſes, by which, the mouth of the pulmonary artery being obſtructed, the right cavities of the heart become monſtrouſly enlarged, and at length burſt, while the left remain empty. Laſtly, from injections; for water, fiſh-glue, and milk, are very eaſily forced, from the pulmonary artery into the vein, and from thence into the left cavity of the heart. But the direct anaſtomoſes or final openings of the arteries into the veins in the lungs, is proved even to the ſight by the microſcope, in frogs, &c.

CIX. Nor can the blood which has once entered the pulmonary artery return back again upon the heart; becauſe the valves therein (CVI.) are of ſuch dimenſions, that when diſtended, they perfectly ſhut up the opening at the heart; and are ſo ſtrong that they reſiſt a much greater force than the contraction of the pulmonary artery, without being conſtrained to yield. However, ſometimes, from a greater contractile force of the artery, they grow ſomewhat callous; or, from a laceration of their outer membrane, a bony matter is poured in betwixt the duplicature of the valves. For, when the blood, by the contraction of the artery, returns towards the heart, it meets and enters the open ſail-like concavities of the valves (CVII.) which are by that means expanded, and driven together towards an axis in the middle: whence the valves, once expanded, quite ſhut up the mouth of the artery, ſo as to leave not the leaſt ſlit open; for any opening that might be left, is precluded by the ſmall callous bodies remarked at CVI.

CX. The *pulmonary veins*, of which we ſhall ſay more hereafter, gather into larger branches, which, at laſt, terminate in four (ſeldom two, and ſtill more rarely into five) trunks; to which it has been cuſtomary to affix a name in the ſingular, by calling them the *pulmonary vein*[50]. Theſe enter the cavity of the pericardium, from whence they receive an external covering; and are then inſerted at angles into the ſquare left or *poſterior ſinus*, which is ſometimes likewiſe called the pulmonary ſinus. In this courſe the upper veins deſcend as the lower ones aſcend. But that theſe veins bring their blood towards the heart, in the ſame direction with the ſinus into which they open, is proved by a ligature, which cauſes a turgeſcence or ſwelling, from the blood retained, betwixt the ligature and the lungs.

CXI. This pulmonary ſinus, which is almoſt of a cubical figure, being firmly built of divers bundles of fibres running betwixt two membranes, has, forward and to the right, one ſingle ſide or partition, in common to itſelf and the right ſinus (LXXXVI.); but forward and to the left ſide, it goes into a conical appendix, which is divided into proceſſes or indentations, like a cock's comb; and, after two or three ſerpentine turnings, makes what is called *the left auricle*, incumbent on the left ventricle, and pointing forwards. Some of its fibres, as in the right auricle, by their bending, contract it into the form of an arch; others, coming from the origin of the appendix, and inſerted into its apex, depreſs it. This ſinus, with the left auricle, are ſomewhat leſs than the right ſinus and auricle.

CXII. In this left ſinus, the blood waits for the heart's relaxation; at which time the niſus of the blood impelled againſt the venous valves, and the contracting ſtronger force of the ſinus, grow leſs. Then the left ſinus ſtretches itſelf forward acroſs the heart, is contracted tranſverſely along with it, and the appendix becomes

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[50] The name of *ſinus venarum pulmonalium*, inſtead of *left* or *poſterior*, is for the ſame reaſon more proper, as this ſinus receives the pulmonary veins as the right does the cavæ.

comes evidently ſhorter and narrower. Thus the blood is driven into the left ventricle, in like manner as the right auricle impelled its blood into the right ventricle, (XCV.) For here, as before, a like membranous oval ring forms productions called *mitral valves*[51], of which there are uſually two only counted. Theſe valves are longer and ſtronger than thoſe of the right ventricle. They have each its own and ſeparate muſcular ſtructure; but it is much firmer than that of the tricuſpids. And here, more often than in the valves on the right ſide, we find cartilaginous tumours in the tendinous ſtrings, produced by the friction occaſioned by the great motion of the heart.

CXIII. From what has been ſaid, then, it appears, that the ſame blood is now arrived into the left ventricle of the heart, which was a little before ſent from the venæ cavæ into the right auricle (LXXXIX.), which drove it into the correſponding or right ventricle (XCV.); by which, again, it was urged into the pulmonary artery (CV.); and, from thence paſſing into the pulmonary veins, was conveyed into the left ſinus (CX.); and, out of this, we here find it driven into the left ventricle (CXII.). This courſe of the blood, from one ſide of the heart to the other through the lungs, is called the pulmonary or leſſer circulation, and was known to many of the ancients. It is proved by the increaſed bulk of the pulmonary veins on the left ſide; and likewiſe of the right cavities of the heart, from an obſtruction of the entrance into the left ventricle.

CXIV. The *left*, or poſterior, and upper *ventricle*[52] of the heart, which is always firſt formed, and in a great number of animals the only one, makes up that part of its half cone-like body, which we before called obtuſe, (XCI.) It is ſome what narrower than the right ventricle, a little longer, rounder, and generally of a leſs capacity within. For the contents of this ventricle, are about two ounces, while thoſe of the right approach to three. Its fabric internally is reticular, but more nicely wrought than in the right ventricle; and within the mouth of the artery it is ſmooth: but its force is conſiderably greater, as the muſcular fleſh that ſurrounds it is much thicker and almoſt three times ſtronger. The ſeptum of the heart belongs moſtly to the left, but ſome part of it alſo to the right ventricle: the whole of it is reticulated in like manner; but ſolid, and incapable of ſuffering any injected liquid to paſs from one ventricle to another[53].

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[51] They ſomewhat reſemble a mitre: however, I prefer the name of *valvulæ venoſæ ventriculi aortici;* which appellation cannot be confounded with any other.

[52] This I would call, on account of the riſe of the aorta from it, *ventriculum aorticum.*

CXV. Again, this left ventricle, being inſtigated to motion by the impelled blood, does, from the ſame irritable nature before mentioned (CIII.), contract, and drive its contained blood with a violent motion in the direction of its axis, and determine it towards the baſis, at the time when the tip or cone of the heart is drawn nearer to its baſis. And ſince the apparatus of the *mitral valves* is here the ſame as in the tricuſpids, the venous blood now expanding the ring from whence they ariſe, removes that valve which lay againſt the mouth of the aorta, ſo as to open a way for itſelf to the artery; in dilating the mouth of which, the ſaid blood preſſes the ſemilunar valves, there placed, againſt the ſides of the aorta, into which it ruſhes with a violent impetus. This is proved by ocular demonſtration in living animals, where the left ventricle ſwells upon ſhutting the paſſage into the aorta.

CXVI. The *ſemilunar valves of the aorta* differ little from thoſe in the pulmonary artery: only as the opening is here greater, ſo the valves are proportionably larger and ſtronger, and are not ſo often found to want thoſe callous round bodies in the middle. The fibres too of the valves, both tranſverſe and aſcending, are here ſomewhat more conſpicuous.

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[53] Among the more rare varieties of parts, unleſs we chooſe to term it a diſeaſe, I would rank the caſe of a girl of ſeven years, who had a double exit from the pulmonary ventricle. For a little below the mouth of the pulmonary artery, another opening, ſomewhat leſs than the former, led into the true arterial duct of Botal, ſent into the aorta. The duct itſelf was perfectly open, as is uſual after birth: The aorta, therefore, in this ſubject, for ſeven years, received blood from each ventricle; the ſeptum, however, being all the while entirely ſound.

CXVII. After the contraction of the heart, follows its relaxation or diaſtole, in which it becomes empty, lax and ſoft, recovers its former length, the ventricles recede from the ſeptum, and the baſis from the apex. But, while it is in this ſtate, the blood in the auricles, having been as it were in a ſtate of expectation, ruſhes through the openings of the valves of the veins, dilates the oppoſite ſides of the heart, and makes it at once longer and larger. After the auricles have freed themſelves of the blood they contained, they are in like manner relaxed, and their oppoſite ſides remove from each other. Then the blood, collected in the venæ cavæ and pulmonary veins, fills the auricles by the contraction of the veins; renders them long, broad, and thick, like the ventricles; and even diſtends and fills the tooth-like proceſſes of the creſted margin. That the fibres of the heart are not dilated, is proved from the junction of thoſe fibres; which, being tied together by their middle branches, cannot be ſeparated: alſo, by the diſſections of live animals, in which the whole heart is ſhown to be contracted.

CXVIII. But we muſt now conſider, that theſe motions of the right and left auricle, with the right and left ventricle, are not performed in that ſucceſſion in which, for the ſake of method, we have here deſcribed them; for both the auricles are contracted, while the ventricles are relaxed: ſo that the contraction of the auricles precedes the contraction of the ventricles; as we are aſſured from manifeſt experiments on dying animals, and on thoſe whoſe living blood is cold. But both auricles are filled together in the firſt inſtant, as both of them are emptied together in the ſecond inſtant; and both the ventricles are contracted together in the third inſtant, which is the ſame with the firſt; and both ventricles being evacuated, are relaxed in the fourth inſtant, which is the ſame with the ſecond. Thoſe who have inadvertently taught otherwiſe, have not taken the advantage of making a ſufficient number of experiments on living animals[54]. That the auricle, near death, makes frequent palpitations before the ventricle of the heart performs one contraction, is true enough. The auricle with its ſinus forms one cavity, and both are filled and both emptied in the ſame inſtant.

CXIX. But it may be aſked, Why the heart never ceaſes from *its perpetual motion*, through ſuch a number of years as there is in one's life, through ſo many days as there are in a year, and through ſo many hours as there are in a day; when, in each hour, the heart of a healthy perſon contracts not much leſs than 5000 times; ſo often are there ſucceſſive repletions followed with new contractions, perpetually in the ſame conſtant order; nor is there any muſcle, beſides the heart and diaphragm, but what becomes tired and painful, by acting inceſſantly, even for a few hours? Different anſwers have been given to this queſtion by different profeſſors, founded either upon a compreſſure of the cardiac nerves betwixt the large arteries, or upon an alternate repletion of the coronary arteries and cavities of the heart, &c.

CXX. But to me the ſimplicity of nature ſeems very great in this matter. When the auricle is relaxed, it is directly filled by the muſcular force of the continuous great vein; and ſo the heart alſo contracts itſelf, when it is irritated by the blood driven into it from the auricle. Therefore, the heart, having once received the blood, is contracted by that ſtimulus or, or irritable force, whereby muſcular fibres are excited into contraction; whereupon it empties itſelf of the blood; and being freed from the ſtimulus thereof, immediately reſts or relaxes itſelf. But the heart being now relaxed, the auricle is in like manner irritated by its contained blood, and by contracting fills it again; while the inceſſant actions of the heart and arteries continually urge new blood into the right ſinus and auricle. That this is the true ſtate of the heart's motions, is proved from actual experiment or obſervation; whereby we plainly diſcern the ſucceſſive repletions and contractions made in the great vein, auricle, ventricle, and artery, eaſily ſeen in a weak or expiring animal; but more eſpecially, and more evidently, in thoſe animals which have but one ventricle in the heart; as the tortoiſe, frog, ſnake, fiſhes; and in the chick hatching in the egg, which, inſtead of a heart, has only one crooked canal. Beſides, it is confirmed from the inertia of the heart, produced by tying the veins; and from the return of its motion, when the ligatures are unlooſed; provided theſe phenomena are ſufficiently valid: but this is more unequivocally corroborated by injection, and by the perpetual contraction of a frog's heart, from the inflation of a bubble of air, which many hours it alternately ejects and receives into the auricle. The left ventricle firſt ceaſes its motion; then the auricle of that ſide; then the right ventricle; after that, the right auricle; and, laſt of all, the pulmonary veins and venæ cavæ. Whatever motion is in the venæ cavæ, ought to be attributed to the auricle repelling the blood into both theſe veins, and which the heart, when dead, is not capable of receiving.

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[54] Obſervations upon living animals, and the reaſon of the thing itſelf, amidſt the three opinions of Lanciſius, Nichols, and Harvey, the laſt of which is very probable, ſeem to ſhow, that at one and the ſame inſtant the two ſyſtems of ventricle and veins are contracted, but that the ſinuſes and arteries are at reſt, or, if you chooſe, are dilated: but when the latter are contracted, the veins and ventricles are at reſt.

CXXI. Nor do I believe there is any thing more required to the heart's motion than a continual ſtimulus applied to a very irritable part. For, juſt upon the approach of death, the very coldneſs of the limbs, which the warmth of life has left, contracts the veins, and drives the blood to the heart; when the lungs, being impermeable for want of reſpiration, tranſmit no blood to the cavities of the left ſide. And, on the other hand, the heart, after it is thoroughly emptied, remains at reſt. It may thus happen, that, inſtead of the vena cava and right auricle, the laſt appearance of life may be transferred to the left auricle and ventricle; if we ſuppoſe the right cavities to be emptied, the left may be irritated by the blood contained in them. But if you derive the reſting of the heart from the compreſſion of its nerves, the motion of the auricles will be an objection, becauſe their nerves are not compreſſed. An example alſo we have in fiſh, and little chicken in the egg, where there can be no room for a compreſſure of the nerves. If, again, you deduce the heart's reſt from a compreſſure the coronary arteries, this is contrary to experience; ſince they are not covered by the valves of the aorta, and from a wound of the ſaid arteries, during the ſyſtole of the heart, the blood ſtarts out to a great height.

CXXII. Nor with the ſtrength of the heart do I join the oſcillations of the very ſmall veſſels, which is refuted by experiments: nor the force of external heat; ſeeing animals are found to live and thrive in the coldeſt regions of the north: and though the contractile force of the artery, and the weight of the parts and of the atmoſphere aſſiſt the motion of the blood during the diaſtole of the heart, the ſame powers reſiſt it during the ſyſtole; ſo that, indeed, by theſe means, the blood is moved no farther through the contractile arteries, than through the rigid arteries of ſmaller animals.

CXXIII. But with what celerity, and with *what force, the heart* drives forward the blood, is controverted, and variouſly computed. The more modern writers have raiſed their calculations upon a ſuppoſition, that, for the celerity to be determined, we are to admit two ounces of blood to iſſue out of the heart with ſuch a celerity, that the part of the pulſe, called its *ſyſtole*, makes one third of the whole pulſation, and is finiſhed within a $\frac{1}{225}$ part of a minute; but the area of the mouth of the aorta, they have eſtimated 0.4187 parts of an inch: ſo, by dividing the ſpace filled by two ounces of blood, (3.318 inches) by the area or ſection of the aorta at its mouth, [and length of its cylinder filled by two ounce, viz.=$7\frac{29309}{33180}$], the number thence produced divided by $\frac{1}{225}$, the time in which the heart contracts, they find 149 feet and two tenths of an inch for the ſpace through which the blood runs in a minute, if it goes on in a cylinder with the ſame velocity it firſt had from the heart. But the incumbent weight of blood moved by the heart, they have computed by the jirk wherein the blood ſtarts forth from the larger arteries in a living animal, being ſeven feet five tenths; and from the ſurface of the ventricle, whoſe area makes 15 inches. Thus 1350 cubical inches of blood, or 51 pounds five ounces, circulate, which preſs againſt the ventricle of the contracting heart. The heart, therefore, thus drives forward a weight of 51 pounds with a velocity by which it may run through 149 feet in a minute; which force it exerts four thouſand eight hundred times in an hour.

CXXIV. Although there are many particulars here unthought of which may render the eſtimate incomplete, and ſuch perhaps as we may never aſcertain; and although the mouth of the diſtended aorta may be wider in a living animal, though the area of the ventricle is of uncertain dimenſions, and the jirk of blood computed from an inſufficient height; yet if we conſider the violence with which the blood ſtarts from ſome of the leaſt ſanguine arteries in the living animal, although we cannot eaſily determine how much of the heart's ſyſtole is thus ſpent, variations in which will greatly alter the computation; yet, in the mean time, it will plainly appear, that the machine we call the heart is a very powerful one. The truth of this is evident from experiments; in which it appears to be very difficult to fill all the red blood-veſſels by anatomical injections, and quite impoſſible to fill all the ſmaller ones: yet the heart, we ſee, not only gradually diſtends all the larger, the ſmaller, and even the leaſt veſſels, with blood, but alſo drives it forward through them with a conſiderable celerity. Even in the leaſt arteries, the blood is urged forward by the heart with ſuch a force as to make the alternate motions of that muſcle perceptible. Likewiſe, in the veins and ſmaller veſſels of cold animals, even while contained in the inſect's egg, there is no other force beſides that of the heart, by which the blood is driven through their ſmall veſſels. And, from ſome of the leaſt arteries, I have ſeen the blood ſtart forth ſeveral feet, the jirk deſcribing a parabola, whoſe height was four feet, and amplitude of projection ſeven feet; and ſome aſſert, they have ſeen the blood aſcend from the aorta to the height of twelve feet.

CXXV. Moreover, that we may make a juſt eſtimate of the heart's force in living animals, we muſt conſider what great reſiſtances that complex muſcle overcomes: we muſt compute the enormous weight there is of the whole blood; a maſs, perhaps, of fifty pounds and upwards: for all that quantity of fluids, once ſtagnant in a perſon lately drowned or fainted away, are eaſily put into their former motion by the heart only[55]. We muſt again conſider the great decreaſe of the blood's velocity, ariſing from the geater light or capacity of the dividing branches, (from whence the ratio of its celerity, even in the inteſtines, may be computed to only a 24th or a 30th part of its original impulſe), abates two-thirds from the heart's force. And yet we ſee there are humours ſwiftly moved through the moſt minute veſſels; as, for example, the Sanctorian perſpiration, which, in a ſubterraneous cavern, I have obſerved to aſcend ſwiftly in form of ſmoke

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[55] The reſults from the lateſt experiments of Marher, Spallanzani, Fontana, Prochaſka, which appear in a contrary light to ſome, do not, when properly conſidered, greatly differ from Haller's opinion of the cauſe of the heart's motion, the change of figure during motion, the force and quickneſs, and duration of the action.

ſmoke or vapour; and the ſame celerity of the blood in the leaſt veſſels of little fiſhes, &c. is apparent to the eye by a microſcope. Now, ſince the frictions, in every machine, always conſume the greateſt part of the moving forces; much more do they in the human body, whoſe blood and juices are ſo much more viſcid or clammy than water, and driven through veſſels ſo ſmall, that they permit a globule only at a time to paſs through, and even hardly allow that without changing their figure: but from ſo ſtrong and extended a friction there muſt neceſſarily follow a very great hindrance to the motion; whence we may eaſily underſtand, that the force muſt be very great, which drives ſo ſwiftly ſuch a prodigious maſs of fluids in ſpite of ſo many reſiſtances and decrements of the moving forces But, more than that, aneuriſms and arteries are burſt, and very great weights, as well as the body itſelf, raiſed by the force of the heart's ſyſtole.

CXXVI. The blood, being driven into the aorta, immediately finds the two openings of the coronary arteries, which lie next the arterial valves, but above them, or within the aorta; and in conſequence of this, it ruſhes firſt of all into the ſaid coronary arteries, by which the heart ſupplies itſelf with blood. Theſe arteries are for the moſt part two; the right goes off between the aorta and pulmonary artery, and the upper and left one between the left auricle and the aorta. All the external arteries are ſurrounded with much fat; but their cavity is more intercepted with valves than that of other arteries. Theſe arteries communicate, by inoſculations of the ſmall branches, every where about the ſeptum and tip of the heart; but they no where make a complete ring round the heart. They terminate in a two-fold manner.

CXXVII. The firſt termination of them is into the coronary veins, whoſe branches running in company with thoſe of the arteries, have their trunks of neceſſity diſpoſed in a different courſe. The *great coronary vein* is, therefore, a companion of the left coronary artery; and is inſerted with a large opening, ſecured with valves, or a number of little membranes, on the left ſide of the Euſtachian valve of the right auricle: the root of this ſurrounds the left auricle externally, and then accompanies the ſuperficial branches of the left artery.

CXXVIII. The other coronary vein (which you may make a part of the former, ſince they have both one common inſertion) deſcends along upon the ſeptum of the heart to its flat ſide; and may be properly called the *median coronary*. The *third* bends tranſverſly round the ſurface of the right auricle; and then terminates within, or at leaſt very near, the large opening of the coronary vein (CXXVII.) anteriorly. This vein ſupplies that part of the right ventricle which lies in the flat ſide of the heart; and often receives thoſe nameleſs veins we ſhall hereafter deſcribe.

CXXIX. There are ſtill ſome other *anterior veins* of the heart; but one more particularly large goes along the adjacent edge of the right ventricle, and, running for ſome length obliquely betwixt the membranes, is inſerted into the moſt anterior part of the right auricle, and ſometimes into the trunk of the upper vena cava. This anterior vein ſends off another concealed one through the root of the right ſinus; and, being again inſerted into the great coronary vein, it makes a complete circle round the heart, like the arterial circle which ſome have deſcribed, but has not yet been ſeen by me.

CXXX. But there are a great many more veins, uncertain in their number, which belong to the baſis and internal parts of the heart, to which the anatomiſt has ſeldom any acceſs, becauſe they lie concealed betwixt the origins of the large veſſels: and theſe open by numberleſs ſmall mouths into the right ſinus and auricle; and ſome, but a few only, into the left ſinus. Thus I have ſeen a particular vein, which, from a latent ſinus in the fleſh of the right auricle, has aſcended towards the aorta and pulmonary artery, and inſerted itſelf on one ſide into the greater coronary vein. Another I have obſerved, concealed betwixt the mouth of the coronary vein and the aorta, inſerted into the right ſinus; and another through the remains of the oval foramen, and ſeptum of the two ſinuſes, inſerting itſelf into the right ſinus; and others again belonging to the venous valves; beſides which, there are ſtill others too numerous to deſcribe. I have obſerved alſo a vein ariſing from the left ſinus and inſerted into the vena cava.

CXXXI. There are ſtill more, and much ſmaller, veins in the heart, whoſe little trunks, being very ſhort, cannot eaſily be traced by diſſection; and theſe open themſelves by an infinite number of oblique ſmall mouths, through all the numerous ſinuoſities obſervable on the ſurface of the right and left ventricle. Theſe are demonſtrated by injections of water, wind, or mercury, puſhed into the coronary arteries, after you have firſt tied their correſponding or accompanying coronary veins; or even into the great coronary veins, after you have firſt intercepted the openings of their largeſt trunks. For, in either of theſe caſes, there are drops of the tinctured water, bubbles of air, ſpherules of mercury, ruſhing out through the whole extended ſurfaces of both the ventricles of the heart; and this, without any violence that can be ſuppoſed ſufficient to break the veſſels. But the paſſage from the arteries into the cavities of the left ſide is more difficult.

CXXXII. There are ſome who will have the coronary arteries filled with blood, not by the contracting of the heart, but of the aorta in its ſyſtole; which they think muſt be a conſequence of the retrograde angle of the blood's courſe here, and the paleneſs of the contracted heart, with a ſuppoſition that the valves of the aorta cover or cloſe the mouths of the coronary arteries. But the two laſt of theſe are diſproved by experience; and the firſt, or retrograde courſe, can only impede or leſſen, and not intercept, the flux into the heart: for the injections of wind or mercury into all the ſeminal and biliary veſſels, demonſtrate that the large retrograde angles, which the veſſels often make there, do not hinder the fluids from taking, though they retard, their natural courſe. But a proof, ſtill more evident, is, that the coronary artery has a pulſe at the ſame time with all the other arteries in the body, and the blood ſtarting from it makes a higher ſaltus at the time when the heart is contracting (CXXI.)

CXXXIII. Concerning the reflux or return of blood from the muſcular ſubſtance of the heart, there is ſtill leſs room to doubt: for all the coronary veſſels diſcharge their blood into the auricles and ventricles, either right or left, (but leſs into the latter), both by the larger (CXXVII, CXXVIII, CXXIX.), the ſmaller (CXXX.) as well as by the leaſt orifices (CXXI.), which ſo eaſily tranſmit injections, after you have firſt tied the larger coronary veins. The circulation thro' theſe veſſels ſeems to be completed in the ſhorteſt ſpace of time that can be neceſſary in any part, from the great velocity the blood receives from the heart itſelf, urging the ſame through its own ſubſtance. But that the whole contents of the veſſels are cleared in each contraction, does not ſeem to me probable; for the blood-veſſels of the heart do not look pale enough in that action to produce ſuch an effect as an entire evacuation. There is a very free or open paſſage from the arteries of the heart into the cellular ſubſtance, or fat which ſurrounds it. If you aſk, What are the uſes of thoſe leaſt or ſhorteſt veins which open obliquely through the ſurface of both the ventricles (CXXXI.)? they ſerve to return the blood of thoſe deeply ſeated ſmall arteries, which have no correſponding veins.

CXXXIV. The humours of the heart, which are thinner than blood, return by the valvular *lymphatic veins*, which accompany the coronary blood-veſſels, and aſcend towards the thoracic duct and ſubclavian vein; but they are to be very rarely ſeen, although I have obſerved them in brute animals.

CHAP. VI.

Of the Nature of the BLOOD *and* JUICES *of the Human Body.*

CXXXV. THE liquor which is contained in the beating arteries and their correſponding veins, is called by one general name, the *blood:* which, to a looſe examination, appears homogeneous, or of ſimilar parts, red and coagulating throughout[56]; and is obſerved to be redder in proportion to the ſtrength of the animal: in a weak and famiſhed one, the blood inclines to a yellow: it hath a whiteneſs mixed with it, which comes almoſt totally from the chyle. But from various experiments it is certain, that this animal liquor contains very different ingredients.

CXXXVI. That fire is contained in the blood may be proved from its heat, which, in human blood, and that of ſome other animals, is from 92 to 100 degrees of Fahrenheit's thermometer, which is more than the mean degree of atmoſpherical heat, but leſs than the greateſt[57]. Again, a kind of volatile vapour or exhalation

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[56] As the blood has various degrees of redneſs in proportion to the diverſity of animals, from their age, food, temperament, and different exerciſe of body; ſo there are ſeveral morbid changes, which convert the blood from an intenſe red to the greateſt paleneſs; whence it becomes liker the vital liquid of more imperfect animals; as we remark in the jaundice, phthiſis, and dropſy, &c.

[57] The heat, which all perfect animals peculiarly poſſeſs in by far a greater degree than vegetables, from the more ſimple claſs of animals, through the various orders of fiſhes, amphibia, man, quadrupeds, and birds, at length gradually increaſes, till for the moſt part, in a natural ſtate, even at its greateſt heat, it does not exceed the 110th degree of Fahrenheit. Daily experience ſhows, that it differs in man, according to age, temperament, ſtate of mind, motion, or reſt of body, climate, weather, kind of life, meat and drink, health, and the various ſpecies and violence of diſeaſe. It is alſo certain that the degree of heat in the body increaſes

lation continually flies off from the warm blood, with a ſort of fetid odour intermediate betwixt that of the ſweat and urine. This vapour, after collection and condenſation in convenient veſſels, partakes of an aqueous nature, with ſomewhat of an alkaline quality.

CXXXVII. After this vapour has diſſipated, the blood of a healthy perſon ſpontaneouſly congeals into a ſciſſile trembling maſs; and with a leſs degree of heat than that of boiling water, (viz. 150 deg.) This toughneſs is greater in feveriſh perſons than in ſuch as are in health. It ſometimes coagulates in the veins of a living perſon, and is found clotted in wounds of the arteries. But even within the veſſels of a living perſon, and in one dying of a fever, the blood has been ſeen, by the violence of that diſtemper, changed into a concreted tremulous jelly throughout all the veins. The principal part of this coagulated maſs is the *craſſamentum* or *cruor*, which has the red colour peculiar to itſelf, and gives it to the other parts of the blood. This, if it be not kept fluid by the attrition of a vital circulation, or ſome ſimilar concuſſion, runs confuſedly into a compact, but ſoft maſs, like liver, merely by reſt and a moderate degree of cold; as it alſo does by the addition

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increaſes a little from an augmentation of heat in the atmoſphere; but it does not riſe to the greateſt pitch of ſummer-heat, although we can live in a much greater heat; as is proved by perſons employed in ſugar houſes, melting furnaces, by mowers, and the uſe of baths and ſtoves in Finland and Ruſſia; and alſo by the late experiments of Fordyce, Blagden, Hunter, and Dobſon. It is ſometimes ſo diminiſhed in an intenſe cold, that in a perſon froſt-bitten, but not dead, a thermometer applied to the mouth, arm-pits, groins, and even the vagina, would not riſe above 76° of Fahrenheit. But is the matter of heat in the blood alone? It is ſufficiently probable from phenomena; ſince the heat of the body is diminiſhed by hemorrhagy, or when the blood is intercepted by ligature and compreſſion from reaching the joints; it being reſtored when the blood returns. I muſt obſerve, however, that my experiments on living animals, particularly upon ſwine, did not diſcover ſo great a difference as might be expected, between the heat of the heart, the arteries, veins, brain, ſtomach, inteſtines, tunica vaginalis, and even the interſtices of the cellular texture in the muſcles.

tion of alcohol, by mineral acids, or by a heat of 150 degrees, of which 98 is the blood's heat in robuſt people. It is, either as a fluid or a ſolid, ſpecifically heavier than water by near an eleventh part; and, when freed from its water, it is wholly inflammable. In a maſs of healthy blood, one half or upwards is red cruor: and, in ſtrong laborious people, the ſerum makes only a third part; and is ſtill more diminiſhed in fevers, often to a fourth or fifth part of the maſs.

CXXXVIII. Another white, ſomewhat yellowiſh part of the blood, ſeparates from this coagulum, tranſuding, as it were, through its pores, and at laſt becomes a quantity, in which the coagulum ſinks: this again ſeems, though not really ſo, a homogeneous liquor. This part of the blood is, in general, one thirty-eighth part heavier than water, and almoſt a twelfth part lighter than the red globular maſs of craſſamentum: this too, by a heat of 150 deg. or by mixture of mineral acids or alcohol, and by a concuſſive motion, is coagulable into a much harder maſs than the red cruor (CXXXVII.); and forms an indiſſoluble glue, a fleſh-like membrane, which at length ſhrinks up to a horn-like ſubſtance, or friable gum. From thence are formed the pleuritic cruſts or ſkins, polypuſes, and artificial membranes. Beſides this coagulable albumen, ſimple water, of which there is the greateſt portion, is latent in this ſerum; and likewiſe a quantity of mucus, leſs capable of being drawn into threads than the red cruor; nor at the ſame time coagulable, like the albumen, by heat and acids[58].

CXXXIX. But by putrefaction only, or the diſſolving power of the air hot to 96 deg. equal to the blood's natural heat, the whole maſs, but eſpecially the ſerum, diſſolves or melts into a fetid liquor; firſt the ſerum, and then the cruor more ſlowly; till at length the

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[58] Haller has elſewhere properly remarked, that the received opinion of the elements of the blood is not hurt by Hewſon's diſcovery of a ſecond kind of lymph, which Krauſius has alſo allowed.

the whole maſs, both of ſerum and cruor, is turned into a volatile and fetid exhalation, leaving very few feces behind. The blood being a little diſſolved by putrefaction, and even before that, becomes fetid; with the fetor it aſſumes an alkaline nature; and efferveſces with acids. This property it afterwards loſes, the alkaline ſalt being deſtroyed by putrefaction. The putrid blood cannot by any art be inſpiſſated, as it is alſo very difficult to be reſolved after it has been coagulated by ſpirit of wine. By too ſevere exerciſe, heat, and malignant diſorders, the coheſion of the blood is diſſolved, and it aſſumes an alkaline nature almoſt as if from putrefaction.

CXL. Beſides theſe parts of which the blood appears to conſiſt, without ſubjecting it to any violence, it contains in its ſubſtance a quantity of *ſea ſalt*, which is diſcernible to the taſte, and ſometimes viſible by the microſcope. That there is *earth* in the blood is demonſtrated from nutrition; and from a chemical analyſis, whereby the earth appears to lodge in the moſt fluid, and eſpecially in the oily parts of the blood. By ſome very late experiments, it appears, that a conſiderable quantity of ferruginous earth, eaſily reducible into metal by the addition of phlogiſton, is contained in the blood when calcined. Laſtly, another part in the blood is *air* in an unelaſtic ſtate[59], and that in a very conſiderable quantity; the exiſtence of which air in the blood and ſerum is proved by their putrefaction and diſtillation, or by removing the ambient air from them by the pump. But we are not to think, from hence, that the blood-globules are bubbles full of air, for they are ſpecifically heavier than the ſerum.

CXLI. By the admixture of neutral ſalts the colour of the blood becomes deeper and brighter, without being either diſſolved or thickened. It is ſcarcely altered by a weak acid. By fermented liquors it is coagulated. Fixed alkaline ſalts have almoſt the ſame effects as the neutrals. The volatile alkalis rather turn it brown, and coagulate it. Alcohol and diſtilled oils, and likewiſe vinegar, coagulate it. It does not effervеſce with any ſalt.

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[59] With the ſame propriety we mention the electric fluid; which, as it is communicated to us by reſpiration, we ſhall briefly conſider in the 8th chapter, along with that inelaſtic gas which has become ſo famous in our time.

CXLII. Chemiſtry has, in various ways, ſhowed us the nature of the blood. (1.) When freſh drawn, before it has time to putrefy, the blood, diſtilled with a ſlow heat, yields a *water* to the quantity of five parts in ſix of the whole maſs; which water has litle or no taſte or ſmell till you come towards the end of the operation, when it is proportionably more charged with a fetid oil. (2.) The reſiduum expoſed to a ſtronger fire, yields various alkaline liquors; of which the firſt, being acrid, fetid, and of a reddiſh colour, is uſually called the *ſpirit* of blood; conſiſting of a volatile ſalt, with ſome little oil, diſſolved in water to the amount of one twentieth part of the original maſs of blood. There is an acid obſervable in the fat, and likewiſe in putrid fleſh and blood. (3.) A little before, and together with the oil, that next aſcends in the diſtillation, dry *volatile ſalt* ariſes, and adheres in branchy fleeces to the neck and ſides of the glaſs; and this in but a ſmall proportion, leſs than an eightieth part of the firſt maſs. (4.) The next liquor is that called *oil* of human blood, which aſcends gradually thicker and heavier, and is at firſt yellow, afterwards black, till at laſt it reſembles pitch, being very acrid and inflammable, but in a ſmall quantity, about a fiftieth of the whole maſs. (5.) There now remains, in the bottom of the retort, a ſpongy inflammable coal or cinder of the blood; which, being kindled, burns away, and leaves aſhes behind. From theſe, by lixiviation with water, is obtained a *mixed ſalt*, partly ſea-ſalt, and partly fixed alkali, together with a ſmall quantity of fixed earth. This fixed ſalt is ſcarce the five hundredth part of the firſt maſs, and of this only one fourth part is alkaline: but being urged with the moſt intenſe degrees of fire, the whole ſalt affords ſome portion of *an acid ſpirit;* which we judge to ariſe partly from the ſea-ſalt in the blood, ſome of which is demonſtrable even in the ſpirit of blood; and partly from the vegetable kind of the aliments, not yet digeſted into an animal nature. For which laſt reaſon, an acid is procurable from the blood of graminivorous animals as well as from that of man. But the *earth*, ſeparated from the lixivium by filtration, will, perhaps, make about an hundred and fiftieth part of the original maſs; and contains ſome particles which are attracted by the loadſtone.

CXLIII. From the preceding analyſis of the blood, it evidently contains a variety of particles, differing in bulk, weight, figure, and tenacity; ſome watery, others inflammable, and moſt of them inclined greatly to putrefaction or to an alkaline nature. For the blood, in a ſound healthy ſtate, not injured by putrefaction, or too violent a degree of heat, is neither alkaline nor acid; but mild or gelatinous, and a little ſaltiſh to the taſte: yet, in ſome diſeaſes, it is ſharp enough, and comes near to a ſtate of puſrefaction; as for inſtance, in the ſcurvy, where it corrodes its containing veſſels; and in dropſies, the waters of which are often next to alkaline. But an alkaleſcent calx is found in the blood of inſects, which effervеſces with acids.

CXLIV. By viewing freſh blood in a ſmall glaſs tube by a microſcope, or by applying the ſame inſtrument, while it is yet moving in the veins of a warm living animal as a hen-chicken, or a cold one as a frog, we perceive in it red globules; which, doubtleſs, make that part called *cruor* or *craſſamentum*, mentioned in CXXXVII. If it be queſtioned, whether theſe are not rather lenticular particles of the ſame kind with thoſe obſerved by Leuwenhoek in fiſh, and lately diſcovered in our own ſpecies; we confeſs it is a point difficult to determine: nor have I ever made a ſufficient number of microſcopical experiments on thoſe globules which ſeem moſt denſe and conevx.

CXLV. The colour of theſe globules is red; and ſo much the deeper and more inclined to ſcarlet the ſtronger the animal is: and in the ſame proportion their number increaſes, when compared with the quantity of yellow ſerum. Their diameter is very ſmall, being between $\frac{1}{20000}$ and $\frac{1}{30000}$ of an inch. They are ſaid to change their figure into an oblong egg-like ſhape, which I could never obſerve with ſufficient certainty. They are alſo ſaid to diſſolve into other leſſer globules of a yellow colour, which I have neither obſerved myſelf, nor can eaſily admit.

CXLVI. From the red part of the blood, fibres are generated in abundance; from the ſerum, in ſmaller quantities: They are procured by pouring the blood into a linen cloth, and waſhing it gradually with a great deal of water, or by beating it with a rod. In quantity, they equal the 28th part of the whole maſs, Theſe are formed of the gluten, and are not generated in a living animal; ſeeing they are neither to be perceived by the microſcope, which ſo eaſily renders viſible the red globules, nor yet does their long thread-like figure ſeem adapted for receiving motion.

CXLVII. From the preceding experiments compared together, ariſes that knowledge which we at preſent have of the blood; namely, that the craſſamentum or cruor is compoſed of globules. The inflammable or combuſtible nature of theſe globules is proved from dried blood, which takes flame and burns; as alſo from the pyrophorus, which is generated from the human blood: and from theſe moſt probably ariſes thegreater part of the pitchy oil that is obtained from blood by the violence of fire.

CXLVIII. The ſerum of the blood diſtilled with a ſtrong fire, gives over almoſt the ſame principles with the cruor, viz. ſalt, oil, and earth. It yields, however, much more water, but no iron at all. Similar principles, but with a leſs proportion of oil and ſalt, are obtained from the aqueous humours prepared from the blood; as the ſaliva and mucus.

CXLIX. The exact maſs or quantity of blood contained in the whole body cannot be certainly computed. The weight of the maſs of humours, however, is much greater than that of the ſolids; but many of them do not flow currently in the circulation, as the glue or jelly that lodges in moſt parts, and the fat. But if we may be allowed to form a judgment from thoſe profuſe hemorrhagies[60] that have been ſuſtained without deſtroying the life of the patient, with experiments made on living animals by drawing out all their blood, joined with the bulk of the arteries and veins themſelves: from theſe principles, the maſs of circulating humours will be at leaſt fifty pounds; of which about 28 will be true red blood, current in the arteries and veins; of which the arteries contain only one fifth, and the veins the other four[61].

CL. Nor does the blood always contain the ſame, or a like proportion, of thoſe elements or principles above-mentioned: for an increaſed celerity, whether by laborious and ſtrong exerciſes, a full age, fever, or otherwiſe, augments the craſſamentum, with the redneſs, congealing force, and coheſion of the particles; and the hardneſs and weight of the concreted ſerum with the alkaline principles, are by the ſame means increaſed. On the other hand, the younger and leſs active the animal, and the more watery or vegetable the diet on which it is fed, the craſſamentum of the blood is proportionally leſſened, and its ſerum and mucus increaſed. Old age, again, leſſens the craſſamentum and the gelatinous part likewiſe.

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[60] The bodies of ſome women, who had died of an uterine hemorrhagy, have been ſent me, whoſe blood, to the quantity of 26℔, was found by chance collected in a veſſel: there appeared the greateſt paleneſs over the whole body, and I found the heart and large arteries and veins completely emptied. In the caſe of a female criminal who was executed, being of a plethoric enough habit, 24℔ of blood were collected, and all the veſſels found quite empty.

[61] Haller has changed this proportion, and indeed he has come nearer the truth; to wit, he has allowed four parts to the arteries, and nine to the veins.

CLI. From theſe principles, but with a conjunct conſideration of the ſolid fibres and veſſels, the different temperaments of people are derived[62]. For a *plethoric*

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[62] The theory of the temperaments of the human body, in the ſenſe commonly recived by phyſicians, and taught in the ſchools, the received diviſion of them into four ſpecies, and their repeated production from the different nature and mixture of the blood, ſavours too much of the ancient and particularly of the Galenical doctrine. I think there can be no doubt, that there are temperaments; and that the manner and rule which nature follows in man, and likewiſe perfect animals, may be obſerved in the performance of the corporeal and mental functions, in either preſerving or endangering the health and life, and in the exerciſe of moſt of the duties and affairs of life, and in the actions of the internal and external parts, which are more or leſs connected with the ſafety of the animal. If, therefore, one would wiſh to give any ſpecific name to this different relation and determination of the parts of our body, when once communicated with the ſyſtem in general, as you would do to any plant, or other particular natural body, and to keep the ancient denominations ſanguineous, choleric, phlegmatic, and melancholic, in preference to all others, he muſt be aware, that, neither the various habits nor temperaments of mankind can originate ſolely from the different nature of the blood, nor all be comprehended under theſe four modifications.

With reſpect to the cauſes of diverſity of temperament, there are many which co-operate. (1.) The various quantity, firmneſs, and ſentient faculty of the nervous ſyſtem, from the brain communicated to each nerve. I have always obſerved a choleric, and cholerico-ſanguineous diſpoſition, in all perſons having a large brain and thick ſtrong nerves, along with a great ſenſibility as well of the whole body as of the organs of ſenſe. Hence ariſes a ready apprehenſion of objects, and an increaſe of underſtanding and knowledge, and, owing to the compariſon of many ideas, an acute and entire judgement, which choleric perſons poſſeſs in ſo eminent a degree; but along with this condition of the nerves, they are exceſſively liable to grief and anger, when the body or mind is but ſlightly affected: and on this account medicines ſhould be cautiouſly given, and leſs doſes preſcribed to them. With a ſmall brain and ſlender nerves, I have obſerved the ſenſes more dull, and a phlegmatic or phlegmatico-melancholic torpor conjoined. Therefore they require from external objects ſtronger impreſſions upon the organs of ſenſe, and longer applied, if they are meant to leave *thoric* or *ſanguine* habit ariſes from an abundance of the red globules; a *phlegmatic* temperature from a redundancy of the watery parts of the blood: a *choleric* diſpoſition of the humours ſeems to ariſe from a more acrid, acid, and alkaleſcent property of the blood; as appears

leave laſting effects: hence their judgment is frequently weak on account of the defect of ideas; and they ſeldom acquire any extenſive knowledge: but nature has compenſated theſe diſadvantages, by making them more able to undergo hardſhips from change of climate, life, or labour; they demand more powerful medicines and larger doſes. What a great difference in man and the cetaceous animals! (2.) The various degrees of irritability in the muſcular parts. For wherever you find a very delicate irritability, affected by almoſt every ſtimulus, and retaining laſting impreſſions, and at the ſame time acting with a certain celerity; in that caſe you cannot doubt of a choleric diſpoſition: hence that remarkable ſtrength in the muſcles of ſome perſons, which acts with ſo incredible quickneſs, diſpatch, and conſtancy. On the contrary, if you examine a phlegmatic perſon, you obſerve the contractile power of the muſcles languid, difficultly yielding to ſtimuli, unleſs powerful; ſince the muſcles of phlegmatico-melancholic men are long of being determined to motion, although ſtrongly excited, and finiſh it with an appearance of languor. (3.) Even a certain ſoftneſs is obſervable in all fibres and membranes, if you touch the body of a phlegmatic perſon; or a ſeeming hardneſs and dryneſs in melancholic habits: along with which particularities the phlegmatic join leſs elaſticity; whilſt in the melancholic there is a greater tone and contractile power. (4.) There is in the air, undoubtedly, a certain electrical principle; which being by reſpiration communicated in different ways with the body, imparts a natural tone to the fibres, occaſions a quicker motion in the veſſels, and increaſes and diminiſhes by turns the alacrity of the mind. But as this principle of atmoſpheric air does not prevail in equal quantity every hour of the day, all times of the year, and in every climate; ſo ſometimes, we feel an univerſal laſſitude, which ſuddenly ceaſes, the ſtrength of the body and mind being reſtored with a ſerene and elaſtic air; ſo in like manner all men do not equally abſorb this electric matter, which thus forms a remarkable diverſity of temperament. (5.) We ought too to combine with theſe the various nature of the blood from the proportion of the elements: and in fact, as greater ſtimuli in the blood excite the heart to briſker contractions; ſo a more acrid and copious bile may effectually promote the periſtaltic motion, and the abundance of mucus occaſion a tendency to lentor and frequent catarrhs.

appears from thoſe who live on fleſh, and on the human ſpecies, being ſo much fiercer and more paſſionate than thoſe who live on plants or on vegetable food. In the ſolid parts, a great firmneſs joined with an exquiſite ſenſibility, or nervous irritability, diſpoſes

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Now, we ſee we have ſufficient cauſes, which from our birth may bring on, in the firſt growth of the parts of the body, an irrevocable determination to this or that habit or temperament. I therefore can ſcarcely admit a complete tranſmutation of temperament, which, during the exerciſe of theſe natural laws, could render a purely choleric perſon phlegmatic: But that ſome change may take place in temperaments, that violent attacks may be mitigated, that lentor, torpor, and liſtleſſneſs may be increaſed, I readily agree; and from the remedies by which ſuch a change may be produced, I form a ſecond claſs of the cauſes of temperaments. The chief are, (1.) A different kind of meat and drink. An animal diet adds a great ſtimulus to our ſtrength, invigorates our ſenſes, and ſometimes induces ferocity; as is evident from the Anthropophagi, carnivorous animals, wild beaſts and their whelps, and hunters, particularly if the abuſe of aromatics, wines, and medicines has ſupervened. Vegetables, on the contrary, increaſe the lentor of the fibres, weaken the ſtrength, diminiſh ſenſibility and irritability; in a word, induce a phlegmatic diſpoſition; in which potatoes have a wonderful effect. It would be of great conſequence to pay regard to this in the bringing up of children, viz. to invigorate the inertia of the mental and corporeal faculties by the uſe of animal food, but to temper the vehement paſſions, peculiar to choleric perſons, by uſing amongſt food a good deal of vegetables. (2.) The particular mode of education, examples. It need ſcarce be inſiſted on of what influence theſe are poſſeſſed, particularly in infancy: hence it happens, that whole nations are of one temperament. (3.) Climate, weather, native country. Rarely in an unſettled climate or country, in hot climates, or in moiſt countries, will you find in choleric perſons that alacrity of temper, agility of body, and quickneſs of underſtanding, which is ſo common in a ſerene and temperate heaven, and high hilly countries. (4.) The increaſe of knowledge. I have often admired that change which a ſtrenuous induſtry produces in ſome of the moſt dull men; ſo that with the increaſe of knowledge, they became of a more cheerful temperament. (5.) Abundance and want of neceſſaries, both in life and for the purpoſe of forwarding improvement. For this reaſon it may happen, that according to the diverſity of the form of government, whether under mild or more ſevere and tyranical laws, the temperament of the ſubject may be either lively or languid. (6.) The ſort of life itſelf, intercourſe with men, and public employment,

may

to a choleric habit; a leſs irritability, with a moderate denſity, to a ſanguine habit; and a leſſer degree both of denſity and irritability are to be referred to a phlegmatic temperament. There is alſo a kind of dull heavy temperament, in which there is the greateſt ſtrength

may have a great ſhare in changing temperaments; ſince rarely after the 36th year of a man's life do you find the blood ſtill pure; and rarely a choleric perſon, who, after 50 years, has preſerved his former alacrity. It is difficult to ſay into how many ſpecies temperaments ſhould be divided, and what kind of character ſhould be aſſigned to each, according to nature and not conjecture. I doubt, I may not be more ſucceſsful than the celebrated Kaempfius and Gerreſhemius, as I exhibit the firſt lines only. The ſanguineous and phlegmatic temperaments, ſeem with various intermedia to comprehend all modifications. (1.) Then, the ſanguineous, which is inconſtant and not well ſpecified, is diſtinguiſhed by a vivid colour of the face; the veſſels are full; and hence for the moſt part they take ill with external heat; they are prediſpoſed greatly to inflammable diſeaſes; they have a great ſhare of ſenſibility and irritability, which all therefore indicate a deſire of pleaſure in this temperament, and the greateſt inquietude both of body and mind prevails: they are talkative; abide not long with any occupation; they are eaſily ſeduced, and contract an intimacy with every body; but they ſoon forget their friends, ſhowing a certain diffidence to all of them; they ſeldom meddle with affairs of any conſequence, and rarely acquire proficiency in the ſciences, unleſs in an advanced age. (2.) The ſanguineous-choleric enjoys a better mixture of cauſes; it has the ſupports of health and cheerfulneſs along with the former, but has perſeverence in common with the choleric. (3.) The choleric: Here you will always obſerve the body tender, though not emaciated and dry as is the caſe with the melancholic; the ſkin is of a whitiſh yellow, with red hairs; the balls of the eyes are of a moderate magnitude, the pupil being frequently dim; a penetrating lively countenance, ſometimes joined with a degree of ferocity; a quick pulſe; actions of the muſcles in walking, ſpeaking, and other reſpects very rapid; copious and acrid bile; hence an effectual periſtaltic motion, more frequent ſtools, a ready inclination to undertake any thing of conſequence, formed as if to command, and particularly fond of animal-food. (5.) The hypochondriac: An unhappy temperament, troubleſome to itſelf and others. Men of this ſort for the moſt part are ſubject to diſeaſes in the liver, have a yellowiſh appearance, always diſcontented, wonderfully tortured with envy and diffidence and are called by ſome *cholerico-melancholic*. (6.) The melancholic have a dejected aſpect: The eyes for the moſt part ſmall, retracted, and winking, the hair black and ſtrength of body, joined with no great degree of irritability. In the melancholic, again, a weakneſs of the ſolids is joined with the higheſt degree of nervous irritation or ſenſibility. But you muſt be careful not to take theſe temperaments as the ſole and limited ſyſtems or claſſes of conſtitutions; which, in the courſe of nature, are found to be not only four, or eight, but are really diſtinct in numberleſs degrees.

CLII. The red part of the blood ſeems chiefly of uſe to generate heat, ſince its quantity is always in proportion to the heat of the blood. This being confined, by the largeneſs of the globules, within the red and firſt order of veſſels, hinders them from collapſing; and, in receiving the common motion of the heart by the greater denſity of its parts, it has a greater impetus, and ſets in motion the leſſer orders of humours. Nor is it improbable, that the heart is more ſtrongly irritated by the ponderous cruor of the blood. The globular figure of its parts, together

and ſkin rigid, remarkable for its dryneſs and leanneſs; a ſmall and ſlow pulſe, ſparing and black bile, a ſlow periſtaltic motion. They indeed have quick perceptions, and ponder long; they ſubmit to toilſome labour with the greateſt patience, but finiſh it with incredible ſlowneſs: for the moſt part they pay no regard to time. They eaſily bear the diſadvantages of life; but when once their anger is excited, they love revenge. (7.) The bœotic or ruſtic joins a great ſhare of the ſanguineous temperament with the melancholic and phlegmatic. The body is luſty, full of juices, a ſmall irritability in its ſtrong muſcles, and ſome ſtupor in its ſmall nerves. Perſons of this ſort are capable of no education; and whatever they undertake ſavours of a low turn of mind. (8.) The gentle and mild temperament: this is compoſed of the ſanguineous, choleric, and phlegmatic. They are a good race of men, wiſhing well to all: in them we always perceive a calmneſs and ſweetneſs of manners; they ſtrongly hate a prating, noiſy loquacity: if devoted to ſtudy, they calmly undertake the taſk, anxiouſly ponder what they learn, and are capable of great proficiency. (9.) The ſlow phlegmatic is diſtinguiſhed by a ſoft and moſtly whitiſh ſkin, a very lax body, very prominent eyes, drowſy aſpect, a ſlow pulſe and walk: for the moſt part they ſpeak ſlow, are patient of the weather's inclemency and other people's affronts; born to obey; and on account of their ſlight irritability, difficultly enraged, and eaſily pacified again.

with their denſity, makes it eaſily pervade the veſſels; and the quantity of iron it contains, as well as of oil, perhaps increaſes its power of generating heat. And hence it is, that the red part of the blood being too much diminiſhed by profuſe bleedings, there follows a ſtagnation or leſſened motion of the humours in the ſmaller veſſels; whence fatneſs, and dropſy. By the ſame rule alſo a due proportion of cruor is neceſſary within the habit, to generate and repair new blood. For, by large hemorrhagies, we ſee the blood loſes its red or denſe nature, and degenerates into a pale, ſerous, or watery ſtate.

CLIII. The coagulable ſerum is more eſpecially deſigned for the nutrition of the parts, as will be hereafter more apparent. Chap. XXXI. The thinner juices ſerve various purpoſes; as the diſſolution of the aliments, the moiſtening of the external ſurface of the body, and ſurfaces of the internal cavities, to preſerve the flexibility of the ſolids, and conduce to the motion of the nerves, the ſight, &c. The ſaline particles ſeem proper for diſſolving the aliment, and ſtimulating the veſſels. The properties of the aërial part are not yet well known. The heat occaſions the fluidity, and is not eaſily raiſed to ſuch a degree as to coagulate the humours.

CLIV. Therefore health cannot ſubſiſt without a denſe and red blood, whoſe quantity too much diminiſhed cauſes a ſtagnation of the juices within the ſmaller veſſels; whence all parts of the body become cold and weak. Nor can life or health ſubſiſt without a ſufficiency of thinner juices intermixed with the red blood; ſeeing the cruor, deprived of its watery part, congeals, and obſtructs the ſmalleſt paſſages of the veſſels, and kindles too great a heat.

CLV. If it is aſked, Whether there be any difference betwixt the arterial and venous blood? we anſwer, That ſome difference ſeems to happen; the former having lately ſuffered the action of the lungs. But, in experiments, I ſcarce find any obſervable difference either in colour, denſity, or any other known diverſity.

ſity. Sometimes, however, I have found a moſt evident difference; for the bright red colour of the arterial blood ſeems to diſtinguiſh it from the duſky dark-coloured blood in the veins; but this, in the plain example of the hatching of a chicken, ariſes only from the deeper ſeries of globules in the thicker vein. But we have not ſufficient certainty of a difference in the blood of different arteries. However, the arterial blood is apparently of a more bright or ſplendid red; and having a greater degree of fluidity and proportion of watery parts, may ſo far differ from the venous darker-coloured blood. But to clear up this, farther experiments are requiſite.

CLVI. From one and the ſame maſs of blood, driven into the aorta, are generated all the fluids of the human body; which, from their affinity one to another, are reducible to certain claſſes. The manner in which they are ſeparated, ought to be accounted for by the fabric or mechaniſm of the glands themſelves. But we muſt firſt conſider what the blood ſuffers from its containing veſſels.

CHAP. VII.

Of the COMMON OFFICES *of the* ARTERIES.

CLVII. THE blood is driven from the left ventricle of the heart into the aorta; which takes its courſe firſt a little towards the right, and then to the left, in an arch that is very ſharply bent: and here the maſs of this purple fluid ſtrikes firſt againſt the right ſide, and is then reflected to the left ſide of the aorta; whence flowing in a vortical or whirling motion as much as that full veſſel will permit, it goes on through the arteries, with an alternate colliſion againſt, and repercuſſion from, their ſides. The aorta ſwells a little in bulk at the place where it proceeds from the heart.

CLVIII. The arteries are, in a living perſon, *always full of blood;* ſince the jet or ſtream that ſtarts

from

from an artery, is not interrupted by alternate ſtops, while the heart reſts or relaxes itſelf, but it flows on in a continued thread: add to this, that the microſcope ſhows the arteries, in living animals, to be full, both in the their ſyſtole and diaſtole; nor can the circular fibres of the arteries ſo far contract themſelves as entirely to evacuate theſe tubes. Since, therefore, a new wave or column of blood is ſent into the arteries, already full, although it bear a ſmall proportion to the whole maſs contained in the arterial ſyſtem throughout the body, hardly ever exceeding two ounces; yet, by its immediate contact with the precedent wave or column, which moves ſlower as it gets farther from the heart, it conſequently drives the ſame forwards, lengthens the artery, and makes it aſſume a cylindric form, augments its diameter, preſſes the membranes cloſer to one another, urges the convex parts of the arterial flexures outwards, and cauſes their ſpiral waves to be more ſerpentine, as injections demonſtrate to us. This dilatation of the artery, whereby its light or capacity is changed from a leſs to a greater circle, is called the *pulſe;* the *diaſtole* of which is an expanſion of the artery beyond its natural diameter. This being the proper or characteriſtic action of life, reſults from the heart only, and is in nowiſe natural to the arteries left to themſelves. Hence when the motion of the heart is intercepted, whether by aneuriſm, ligature, or otherwiſe, there is no pulſation of the arteries to be felt; and hence there is a ſudden ceſſation of the pulſe, by a wound through the heart, in a living animal. But the artery is proportionally more dilated, as the wave of blood flows on before more ſlowly, and the more the velocity of the new wave exceeds that of the former one.

CLIX. The *ſyſtole* or contraction of the artery follows the dilatation of it. For the heart having emptied itſelf, and removed the ſtimulus of the blood, comes into a ſtate of relaxation and reſt. But the artery, at this ſame time, by its innate elaſticity and contractile power reſiding in its circular fibres, irritated likewiſe by the ſtimulus of the blood, contracts itſelf, and expels as much blood as ſerved to dilate it beyond its mean or middle diameter: this quantity of blood is either forced into the ſmaller and ſcarce-beating arteriolæ, or into the veins, as the ſemilunar valves of the aorta oppoſe the return of the blood in the part of that veſſel through which it has juſt now paſſed. So ſoon as the artery has freed itſelf from this wave or column of blood, being no longer ſtimulated by diſtention, it directly collapſes by its own proper contractile force, and is now again ready to yield to a new wave or column of blood ſent into it from the heart; whence follows a repeated diaſtole.

CLX. That the arteries thus contract, and, by that force, propel their contained blood, is proved evidently from their ſtrongly contractile nature; from the apparent diminution of the diameter or dilatation they receive from the heart; from the evacuation that follows, by the proper force of the artery itſelf, driving out all the blood that is contained in the lateral branches betwixt two ligatures; from the return of the blood to the heart through veins whoſe artery is tied, which therefore the heart has no ſhare in propelling; from the wave of blood being greateſt when the heart is in its diaſtole, as obſerved by ſome eminent anatomiſts; from the ſtrength with which the blood is ejected from the tied aorta below the ligature; from the evacuation which the arteries make of their contained blood even after death into the veins, whereby theſe latter appear much fuller than the arteries; and, laſtly, from the conſiderable ſaltus of blood that iſſues from a large artery in an animal even after death, mounting to the height of two feet: to which add, the convulſive contractions of the animal in which the artery is thus wounded, and the remarkable cloſings of the mouths of divided arteries in wounds, and a ſphacelation of the limbs from an oſſification of the artery; whence the veins become diſtended.

CLXI. The mean ſwiftneſs of the blood's motion being diminiſhed in the time of the heart's ſyſtole, but increaſed during its diaſtole, is ſuch as carries it through a ſpace ſomewhat leſs than one foot in the ſpace of a ſecond of time; and the conſtant plenitude of the arteries renders it impoſſible for us to perceive any ſucceſſion in the pulſes of different arteries; whence all the arteries of the body ſeem to beat at one and the ſame inſtant, whilſt the heart ſtrikes againſt the breaſt: and yet there is certainly a ſucceſſion in the ſyſtole of the arteries, by which the aorta ſeems to contract in the ſame order ſucceſſively, as it is filled by the blood expelled from the heart; ſo that the part of the artery next the heart is firſt conſtringed, and thence, gradually, the arterial contracting force proceeds to the extremities. An inſtance of this we have in the inteſtines; and the ſame is evident to the eye in inſects, who have a long fiſtulous and knotted heart, manifeſtly contracting in a ſucceſſion from the beginning to the end. But the mind cannot diſtinguiſh the leaſt points of time, which are the meaſures of this ſucceſſion, and amount only to a few thirds of a ſecond.

CLXII. If it be aſked, Where this pulſation ends? we anſwer, In the leaſt arteries, and cylindrical originations of the veins. We have already mentioned the velocity with which the blood comes from the heart. But that velocity continually decreaſes. Certain we are, (1.) That the lights or ſections of the arteries, compoſed by the aggregation or ſum of their tranſverſe ſections, as they divide farther in their courſe from the heart, greatly exceed that of the aorta; ſo that ſince the ratio, or leſs proportion of the trunks to their branches, continually diminiſhes as they make leſs ramifications, and this in a variable or uncertain proportion; the difference of that ratio or proportion will be the greateſt betwixt the light of the aorta at the heart, and the ſum of the ſections of all the ſmall arteries, where they are leaſt, in the extreme parts of the body. Again, (2.) The proportion of the arterial membranes or coats in thickneſs, with reſpect to their bores or capacities, is greater as the arteries grow leſs; and is largeſt in the leaſt of them, which tranſmit only one globule at a time. The truth of this is proved from anatomy, and the forcing of air into the arteries, by which they burſt always more difficultly as they are leſs; and from the calculation itſelf, by which the magnitude of the leaſt arteries is determined from the globules diſtending their two ſemicylindric membranes. Add to this, (3.) The friction of the juices through the leaſt veſſels, inflected and meeting together in angles; which friction, even in the moſt fluid water, running through long pipes that are ſingle, and in a direct courſe, greatly diminiſhes the velocity, and more in proportion as the tube is of a leſs bore; while again, as the artery is leſs, there are a great number of globules rubbing and grating againſt its membranous converging ſides. And by the conical figure of the artery, it happens, that the broader wave of blood, coming from the trunk, is reſiſted in its paſſage through the narrower branch, and ſo muſt diſtend it by force. But moreover, (4.) The *inflections and folds*, or plates of the veſſels, greatly ſlacken the blood's motion; ſince always ſome part of the impelling force is ſpent and loſt in removing the convex parts of the folds, and changing the figure of the inflected veſſel. The angles likewiſe take off more from this force in proportion to their acuteneſs, or the more they recede from a ſtraight line. Laſtly, (5.) A conſiderable allowance muſt be made for the great viſcidity or tenacity of the blood itſelf; ſince, by reſt only, it directly hardens into clots; and ſince it is from the circulatory motion only of the blood, that this mutual attraction of parts is overcome, ſo as to hinder it from adhering to the ſides of the arteries; for ſo we find it adhere in anueriſms and wounds of the arteries, or elſe the globules clot together, as we ſee uſually after death. From all which conſiderations, you will obſerve, that the blood meets with the greateſt retardation in its courſe in the leaſt veſſels. And the oppoſition it meets with in the branches leſſens the velocity of the blood alſo in the trunk: the oppoſition of torrents of blood to one another in the anaſtomoſes of veſſels alſo deſtroys ſome parts of its motion. We may eaſily perceive the amounts of this retardation will be very conſiderable, although it be difficult to eſtimate it juſtly. In the larger trunks the blood of a living animal flows with the rapidity of a torrent: but, in the leaſt branches, it creeps along very ſlowly; ſo that in theſe it begins to put on a ſtate of coagulation. It is alſo well known to ſurgeons, that a ſmall branch of an artery near the heart or aorta bleeds more dangerouſly than a much larger one that lies at a greater diſtance. The weight of the incumbent atmoſphere, of the muſcles and fleſhy parts lying above the artery, and the contractile power of the veſſel itſelf, make a reſiſtance indeed to the heart; but do not leſſen the velocity of the blood, ſeeing they add as much in the diaſtole as they diminiſh in the ſyſtole.

CLXIII. It is certain, however, from inciſions made in living animals, that the ſingle globules of blood, which move ſeparately in the ſmall veſſels, do not loſe ſo much of their velocity as, by calculation, they ought to do. We muſt therefore aſſign ſome cauſes by which this power, deſtructive of the blood's motion, is leſſened. And, in the firſt place, it is certain, that the lights of the branches do not bear ſuch a proportion to the trunk in the ſmalleſt veſſels; their great ſmoothneſs diminiſhes the friction. The facility likewiſe with which the blood flows through the veins, expedites its paſſage through the little arteries, which immediately communicate with theſe veins. No great help is to be expected from conſidering the effect of ligatures or the weight of the blood, which is capable both of diminiſhing and accelerating the motion; nor can we ſuppoſe that in live animals a great effect depends upon the force of the nerves. The power of derivation, whatever that is, and the motion of the muſcles, are capable of producing a new velocity.

CLXIV. The pulſe therefore enſues, becauſe the anterior wave or column of blood moves on ſlower, while the ſubeſquent or poſterior wave comes faſter; ſo that the preceding is an obſtacle to the conſequent blood (CLVIII.). But ſince the force of the heart weakens as the blood goes on, and the contractile power of the arteries increaſes, therefore the diſproportion of celerity betwixt the antecedent and conſequent waves or columns of blood coming from the heart, will be continually leſſening with reſpect to the blood that is urged on by the contraction of the ſmaller veſſels, till arriving at a part where there is no exceſs or difference, it will there ceaſe to make any pulſation of the artery; becauſe here the anterior and conſequent blood flow evenly, or with the ſame celerity. But this place of equality in motion, cannot be in the larger and more conſpicuous arterial branches: for in them the wave, laſt coming from the heart, moves quicker than what went before; as is evident from the inflammatory pulſation of them, eſpecially in the ſmall arteries of the eye. But, in the leaſt red arteries, the pulſe at length begins to vaniſh. This is evident from the equable motion of the blood, often ſeen by a microſcope through the arteries of a frog. In the larger veſſels, however, ſuch as may be about the ſixth part of a line in diameter, the pulſe is perceptible. But in the leaſt veins viſible to the eye, there is no ſenſible pulſation or accelerated motion of the blood, whilſt the heart contracts, demonſtrable either by the microſcope or any other experiment.

CLXV. Even in the veins, the blood preſſes againſt their ſides, as appears from the furrows hollowed out of the bones, and the ſwelling of the veins on being tied. If it be aſked, Why the veins do not beat? (for we do not allow that to be a pulſe which happens from reſpiration, from the rejection of the blood from the right auricle, or from the muſcular part of the vena cava); the reaſon of this ſeems to be, that the blood, immediately on its leaving the heart, is more retarded in its motion than when it paſſes into the ſmalleſt veſſels. Hence, the ſhort ſpace of time by which the velocity of the laſt wave exceeds the foregoing, is greateſt at the heart, and grows gradually leſs, till it at laſt totally vaniſhes. This is illuſtrated by the experiment, in which a pipe, fixed in a leathern tube, and driving forth water in a continual, but ſtarting ſtream, does, by a ſponge fixed round the mouth of the ſaid tube, cauſe the water to iſſue forth in an even ſtream, without leaping through the ſponge: and the ſame is evident from another experiment, in which the ſame thing happens, by injecting the meſenteric arteries with an alternate impulſion of water; for then the water flows out through the veins in one continued even ſtream.

CLXVI. The *pulſe* is therefore the meaſure of the powers which the heart ſpends on the blood; becauſe it is the immediate and full effect of thoſe powers. Hence, all things conſidered as alike, the pulſe is *ſlow* in the moſt healthy people, where there is no ſtimulus, nor any unnatural reſiſtance to cauſe the effect of a ſtimulus, but the heart is at liberty to ſend forwards the blood with eaſe. You muſt except thoſe caſes where there is ſome obſtacle, by which the blood is prevented from entering the aorta. For this reaſon the pulſe in aſthmatic people is ſlow: the ſame thing alſo happens from a debility or inſenſibility of the heart, which the uſual ſtimulus is not capable of exciting to contraction. A *large* pulſe is cauſed by fulneſs of the artery, joined with a ſtrong force of the heart; a ſmall pulſe by the emptineſs of the artery, and a leſſer wave of blood ſent from the heart. A *hard* pulſe denotes ſome obſtacle or ſtimulus; or elſe that the heart's force is increaſed with a greater thickneſs of blood, or a greater rigidity of the artery. A *quick* pulſe denotes ſome ſtimulus, obſtacle, or greater ſenſibility or irritability of the heart. It is beſt felt where the artery lies expoſed bare to the touch, upon ſome reſiſting bone; but obſtructions ſometimes render the pulſe perceptible, where it is never ſo naturally.

CLXVII. The pulſe is ſlower in animals as they are larger or more bulky; becauſe the heart is proportionably bigger in the ſmaller than in the larger animals, and, as well as the other parts of the body, is more irritable in the former than in the latter; and becauſe the heart is obliged to drive the blood to a greater diſtance; whence the reſiſtances or frictions in the more bulky ſeem to be increaſed more than the force of the heart. Hence, ſmall animals are more voracious; and large ones, as the whale and elephant, eat leſs. The pulſe of a healthy perſon riſing in the morning, beats 65 in a minute; but, after the fatigue of the day, it will beat 80 in that time; and again, by the night's reſt or ſleep, it will become gradually leſs frequent, till in the morning you will find it returned to its primitive number of 65. For the motions of the muſcles, and actions of the external and internal ſenſes, the warmth of the atmoſphere, and the action of the aliments taken into the ſtomach, urge the venal blood on to the heart, which being thereby oftener ſtimulated, makes more frequent contractions. This is the cauſe of thoſe paroxyſms or fits of increaſe obſervable in all fevers towards the evening. For ſleep not only retards the motion of the blood, but of all the other humours and actions in the body whatever.

CLXVIII. A frequent pulſe is different from a ſwift one; and it is poſſible for the pulſe to be at the ſame time ſwift and unfrequent. But it is difficult to obſerve a ſwift pulſe. The frequent pulſe is what is commonly called a *ſwift* one, It takes place in children, and becomes afterwards ſlower in perſons as they grow older. The ſalient point beats 134 in a minute: new-born infants have their pulſe 120 in that time; and from thence down to old age it grows ſlower, to 60 in a minute. A feveriſh pulſe begins from 96 per minute; and we count the pulſe has but a moderate celerity in fevers, or laborious exerciſes of adult perſons, if it does not exceed above 110 or 120 in a minute: but it is exceſſive at 130 or 140, with which number people ſeldom recover; nor have I ever obſerved it exceed that number. The pulſe beats ſlower in winter, and quicker in ſummer, by about 10 ſtrokes per minute; and under the torrid zone, it grows quicker to 120[63]. The different paſſions of the mind variouſly accelerate, retard, and diſturb the pulſe. Whatever obſtructs the circulation is alſo found to accelerate the pulſe; not from the laws of hydroſtatics, or on account of the canal being made narrower, nor from the action of the ſoul; but only the heart being with more difficulty freed from the ſtimulating contracts itſelf more ſtrongly, and at ſhorter intervals. An irritation from an acrid blood is the cauſe of the frequent pulſe in fevers.

CLXIX. Through the leaſt veins the blood moves on very ſlowly, partly by force of the heart, and partly by the contractile force of the arteries. The firſt is proved by a renewal of the motion of the blood in perſons drowned; where, merely by exciting the action of the heart, the whole maſs is again propelled. But the contractile force of the artery is proved by what is ſaid (CLX.). But after death the blood continues to move, in part, alſo by its own gravity, and by the elaſticity of the air generated or extricated by putrefaction.

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[63] I obſerve a wonderful difference in the pulſe, as it depends upon temperament: for in a ſanguineous and choleric habit the pulſe is more frequent, let the age, ſex, and ſtate of mind be what it will; in a phlegmatic and melancholic perſon, it is ſlower. But the whole doctrine concerning the pulſe, though you even ſlightly eſteem ſome of the too ſubtile diſtinctions of the French, and the prognoſtics in diſeaſes reſulting from theſe, is, however, much indebted in the preſent age to the induſtry of ſome of the moſt reſpectable men; ſome of whom Haller has mentioned, and among whom Gruner, Stedman, and others, may alſo be ranked.

CLXX. But the blood moves on faſter in the larger veins. For whenever the impelling powers remain ſufficient, and the conveying ſmall veſſels are rendered narrower, the motion of their contained fluids muſt of courſe be accelerated; ſince the ſection of the venal trunk is much leſs than that of all its branches, in the ſame manner as that of an artery is leſs than the ſum of the branches into which it divides. Therefore if the motion of the venal blood loſes nothing in its way, the proportion of its celerity in the vena cava, to its celerity in the veins of the thirtieth diviſion, will be thirty times greater in the former, in proportion as the conjunct lights of all the ſmall veins exceed the light of the cava. In like manner, too, the friction or attrition of the blood in the veins, and its contact with their ſides, diminiſh.

CLXXI. But ſince the blood moves thus ſlowly in the leaſt arterial veſſels and incipient veins, and as the weight of the blood itſelf, in many places wonderfully hinders its return to the heart, while, at the ſame time, the very thin coats of the veins have but little contractile power to be expected from them; therefore nature has uſed various precautions, leſt, from the ſlowneſs of its motion, it ſhould any where ſtagnate or concrete. To obviate this, ſhe has ſupplied the veins with more watery vapours and fluxile lymph, than ſhe probably ſent by the arteries, if we conſider the great exhalation that is made from the arterial blood in the lungs.

CLXXII. She has, therefore, likewiſe placed the veins near the muſcles, that by the turgeſcence or contractions of the latter the veins may be preſſed; and ſince any preſſure upon the veins muſt be determined towards the heart (LXIII.), therefore all this force muſt be entirely employed in accelerating the return of the blood to the heart. From hence proceeds that wonderful quickneſs of the pulſe (CLXVII), heat, and redneſs of the body, with a ſhort and laborious breathing, that attend muſcular motions or violent exerciſes.

CLXXIII. Moreover, thoſe muſcles, which conſtantly urge or preſs violently the contiguous viſcera on all ſides that are contained in any of the common cavities, do all of them powerfully promote the return of the venal blood to the heart. Such an effect has the conjunct preſſure of the diaphragm with the abdominal muſcles, in reſpect to the abdomen. Laſtly, the pulſations of the arteries, which run every where contiguous and parallel to the ſides of the veins, have no inconſiderable effect in promoting the return of the venal blood; ſince, as we have before ſhown, any impulſe acting on the veins can determine their blood to the heart only.

CLXXIV. To theſe is added a force not yet ſufficiently known, by which the blood is brought from a place where it is more compreſſed to one more lax, and where it meets with leſs reſiſtance. In this matter alſo reſpiration is of great efficacy; in which the motion of the blood into the lungs, when relaxed, is accelerated by the power of derivation from all parts of the body: and again, in exſpiration, it is driven into the trunks of the veins in the head and abdomen. Hence the ſwelling of the veins, and likewiſe of the brain, in the time of exſpiration. The circulation is not indeed aſſiſted by theſe cauſes, but the blood is agitated and preſſed. The anaſtomoſes of the arteries contribute to the ſame end; for they render the paſſage of the blood more eaſy from thoſe places where it is obſtructed to ſuch as are more free.

CLXXV. By theſe means, the blood in a healthy perſon, uſing ſufficient exerciſe of body, moves on with ſuch a velocity, as ſuffices to deliver as much of the purple fluid in every pulſe by the vena cava to the heart, as is equal to what is ſent out by that great artery the aorta. But reſt or inactivity of body, and a weakneſs of the contracting fibres of the heart and other muſcles, frequently render this motion of the venal blood more difficult. Hence follow the varices and the piles in women with child; which latter is much occaſioned from the deficiency of valves in the vena portarum. And from hence ſpring even the menſes themſelves. And when the veins too ſlowly return their blood to the heart, the ſubtile vapours, being thus unable to return to the heart, are obliged to ſtagnate; whence proceeds that frequency of œdematous and pitting ſwellings of weak people.

CLXXVI. The time in which an ounce of blood, ſent out from the left ventricle of the heart, returns to the right, and which is commonly reckoned the time in which the greater circulation is performed, is uncertain, and different in every different portion of the body. If, however, you want to know about the ounce of blood propelled in that quantity, which we have mentioned, the amount of it will be about 7½ ounces in an hour with 4500 pulſes; and the amount of the perfect circulations will be about 23½.

CLXXVII. The effects which follow from the motion of the heart and arteries upon the blood are various, which may be deduced and eſtimated from the cauſes themſelves of thoſe effects, if we compare the blood of a living and of a dead animal, that which is healthy with that which is diſeaſed, and that which is inert or too little moved with that which circulates too ſwiftly. For we obſerve, that, in the living, the blood is, (1.) Conſiderably warm or hot. (2.) It looks red, with a ſort of purple ſlorid hue. (3.) It ſeems to be homogeneous or uniform, and alike in its parts; though they are really mixed and of different principles. (4.) It is made up almoſt entirely of globules. (5.) It flows very readily through the leaſt veſſels: From whence being drawn, (6.) It exhales a volatile vapour, which we have already deſcribed particularly. In the dead animal which has not yet begun to corrupt or putrefy, we obſerve, (1.) That it has loſt a great deal of its redneſs. (2.) That it ſeparates into a more denſe and a more thin ſubſtance. (3.) That it exhales no vapour. (4.) Being drawn out from the veins, it congeals either all or the greateſt part. But even in the living animal, when very weak, where there is ſome pulſe or reſpiration, though ſmall, we find the blood cold, even to a conſiderable degree. If, again, you compare the blood of a human perſon, unactive both in body and mind, with the blood of one that is addicted to violent exerciſe, you will obſerve the latter has, (1.) A greater heat. (2.) A more intenſe redneſs. (3.) A ſubſtance more compact, and ſpecifically heavier. And, (4.) The volatile parts more abundant. All which appearances ſeem manifeſtly the effects of the motion of the heart and arteries, ſince they proportionably increaſe and diminiſh with that motion, and diſappear when that ceaſes.

CLXXVIII. That we may underſtand the manner in which theſe appearances are produced in the blood, we muſt conſider what are the effects of the heart impelling the ſame, and of the arteries alternately compreſſing and urging it forward. And firſt we ſee, that the heart drives the blood into the arteries with a very great celerity (CXXIII.) With a confuſed or vortical motion, the heart thus throws the blood into the crooked or inflected arteries, in ſuch a manner, that the right globules, expelled through the opening of the aorta, ſtrike againſt the left ſide of the artery; from whence being repelled, they incline towards the right ſide, whereby all the particles of the blood are agitated with a confuſed or turbulent and whirling motion. The blood thus impelled againſt the flexile and curved ſides of the arteries, of neceſſity dilates or diſtends them into a greater convexity; and, laſtly, in the ſmaller veſſels, capable of receiving only one or a few of the blood-globules, all the ſaid globules come ſo intimately into contact with, and grate againſt, the ſides of the ſaid artery in all their points, that they are even obliged to change their figure in gaining a paſſage into the veins.

CLXXIX. But the arteries, by their elaſtic force, reacting upon the impinging blood, repel the ſame from their ſides towards the axis of the light or capacity; and at laſt tranſmit every ſingle particle of it through the circular mouths of the leaſt veſſels, by which the arteries and veins join together.

CLXXX. There is, therefore, a moſt prodigious degree of friction, as well from the blood globules upon the ſides of the arteries, as from the arteries themſelves contracting round the blood; to which add, the attrition of the particles of blood againſt each other by the confuſed and vortical motion with which they are propelled. The effects of this friction may be computed from the viſcid and inflammable nature of the blood itſelf, from the narrowneſs of the veſſels through which it runs, and from the ſtrong impulſe of the heart, joined with the powerful reaction of the arteries; to which add, the weight of the incumbent parts raiſed by the force of the arterial blood. This friction generates a fluidity in the blood, by perpetually removing the points of contact in its globules, reſiſting their attraction of coheſion, mixing together particles of different kinds, which become more fluid upon mixture, as we have an inſtance in oil when triturated with water. It alſo augments the ſphericity of the particles, by breaking off their protuberances and little branchings. But even theſe very ſmall particles themſelves, which are broken off from the large particles of the blood, put on a round figure by their friction againſt the ſides of the canals, and by their rotatory motion: By deficiency in theſe particulars the blood coagulates in the veſſels before death; and hence the loſt fluidity of the blood is again reſtored, by recovering the motion of the heart, as we are taght by experiments made on living animals. It is a queſtion, whether this motion of the blood, and the denſity proceeding from it, is the cauſe of the red colour of the blood[64], ſeeing

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[64] Even the premiums have been unavailing, which have been propoſed by ſome of the moſt famous boards of ſcience, for diſcovering the

ing the redneſs is in proportion to the denſity, and increaſes or decreaſes from the ſame cauſes. This ſeems to ariſe from a mixture of the ferruginous with the oily part of the blood.

CLXXXI. We may alſo aſk, whether the heat of the blood does not alſo proceed from its motion[65]? ſeeing we obſerve heat to ariſe from the motion of all kinds of fluids, even of air itſelf, in our experiments; but much more does this attrition produce heat in the inflammable animal juices, which are denſer than water, and compreſſed with a conſiderable force by contractile and converging tubes. Is not the truth of this ſufficiently evinced, by the blood's being warm in thoſe fiſh which have a large heart, and cold in ſuch as have a ſmall one? the generation of

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the true cauſe of the blood's redneſs. The primary cauſe has been ſuppoſed to be iron, from the experiments of Menghini and Stormius; and likewiſe the influx of the aërial principle according to Prieſtley; and an inflammable ſubſtance, conjoined with the aërial acid, according to Weigel and other chemiſts opinions. Every hypotheſis has its own difficulties to encounter. If we could demonſtrate ſo great a quantity of iron in the blood as is requiſite to tinge 30℔, and to produce ſuch an appearance of redneſs as blood exhibits, I would without heſitation aſcribe the cauſe to it: but there is too ſmall a quantity; nor does the frequent uſe of chalybeates favour the hypotheſis. The more probable opinion, therefore, is, that ſome inflammable principle, ariſing from the air and our aliments, along with ſome metallic matter, mixed by the vital powers of the body, is the efficient cauſe. Perhaps ſome other cauſes are yet concealed. May any light be diſcovered from the opinion propoſed by Hewſon about the efficacy of the ſpleen?

[65] Although it be eaſier to ſhow, that animal heat is not produced properly from the friction of the fluids upon the veſſels, than to ſubſtitute a more ſatisfactory and probable explication, my own reading and experiments, nevertheleſs, will not allow me to favour this theory. On the contrary, I am perſuaded, that the various ſtates and quantity of animal power in the nervous ſyſtem, the air's quality and acceſſibility, according to the freedom of reſpiration, to our lungs, the motion of the muſcles in their different degrees of increaſe and excitement, conjunctly with the progreſſive motion of the blood, not only produce the vital heat, but diſperſe it, when once produced, through all the body, in proportions which vary according to the greater or leſs ſupply of veſſels in the different parts.

of heat being in proportion to the ſize of their bodies: from the more intenſe heat of birds that have a larger heart, and more frequent or quick pulſations? from the increaſe of animal heat, that enſues from exerciſe of all kinds, and even from bare friction of parts? from the congelation of all the humours of the human body in a certain degree of cold, in which a man grows ſtiff, though he yet retains ſome warm blood and is alive? and from the coldneſs of ſuch people as have their pulſe weak and obſcure? Nor does the heat at all ariſe at firſt from any degree of putrefaction in the blood, ſeeing the humours themſelves, when left at reſt, generate no heat. Nor muſt we explain an evident appearance from the action of ſuch an obſcure being as the *vital power;* and though ſometimes the heat may be greater when the pulſe is ſlow, and leſs when it is more frequent, the difference may ariſe from the different diſpoſition of the blood, from the different denſities of the veſſels, or the increaſe or diminution of perſpiration.

CLXXXII. The ſame cauſe alſo hinders putrefaction, by not ſuffering the inteſtine motion to be diminiſhed, and by diſſipating ſuch particles as have already begun to be corrupted.

CLXXXIII. But the different natures of the ſeveral particles themſelves, which conjunctly make up the maſs of blood, are the cauſes by which, from one and the ſame impetus of the heart, different effects or conſequences are produced in different particles of the blood: Namely, thoſe particles move quicker, whoſe greater denſity makes them receive a greater impetus, and whoſe apt figure or leſs extended ſurface makes them meet with leſs reſiſtance in the fluid in which they move. Thoſe alſo are driven along more ſwiftly, which, either from their weight, or from the direction in which they paſs out from the heart, are urged chiefly into the axis of the veſſel. Thoſe again will ſtrike againſt the convexities of the flexures in the arteries, which have the greateſt projectile motion;

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while the other parts of greater bulk and tenacity, having leſs projectile motion, will move ſluggiſhly along the concavity of the veſſel. And in this manner is the blood prepared or diſpoſed for the ſeveral ſecretions.

CLXXXIV. The *ſyſtole* of the arteries renders the parts of their contained fluids more denſe or compact, while they contract round the blood as round a ſolid obſtacle; which being in ſome parts viſcid and compreſſible, they drive and expel the more liquid parts into the lateral mouths or ducts, at the ſame time increaſing the points of contact betwixt the globules themſelves, combining their more large and denſe ſpherules, and compacting the flat particles into denſer bodies. But the denſity of the blood is partly as the number of globules, and partly as the denſity of the materials whereof theſe globules are compoſed.

CLXXXV. Moreover, the mouths of the leaſt veſſels pervious to only one globule at a time, ſeem to be a ſort of moulds to figure and break off the angular eminences of the particles in the blood, and bring them to a ſpherical figure; which at length they put on, and change into perfect ſpherules. Laſtly, from hence ariſes the denſity of thoſe particles; ſince, of all figures, ſpheres contain the moſt within a given ſurface.

CLXXXVI. The *reticular* diſtributions and inoſculations of arteries remove any danger of obſtruction; ſince in any part of the artery where the blood cohering begins to form an obſtruction, a contrary flux is admitted, by which the obructing matter is repelled to a larger part of the trunk; and thus betwixt the reflux and the direct torrent of the blood, the ſaid matter is broken and attenuated. This mechaniſm alſo ſupplies the deficiency from an irremovable obſtruction or the loſs of a veſſel, by cauſing a greater diſtenſion or enlargement of the next adjoining or anaſtomoſing veſſel; as is proved by experience in ſurgery, after tying and cutting a great artery. The colliſion of theſe oppoſite torrents of blood take ſomething from its velocity; and the reticular diſtribution augments the friction of the globules.

CLXXXVII. As the quicker motions of the blood in the trunks conduce to ſanguification, ſo the ſlower motions of it, in the leaſt veſſels, have their effects towards the ſecretions. In the larger arteries, we ſee the different particles of the blood are whirled about amongſt each other with a rapid and confuſed motion; but, in the leſſer ramifications, the progreſſive motion of the blood being diminiſhed, the more looſe colourleſs particles depart laterally from the more denſe and red globules, while the latter keeping on their courſe more firmly along the axis of the veſſel, expel the former laterally and to the circumference. Thus the attractive powers of the particles in the blood increaſe as their progreſſive motion abates; hence, the oily or fat particles are drawn one to another, and go off by the open lateral ducts that lead to the cellular ſubſtance; which particles we know are both groſs and ſluggiſh: and again, other thinner juices are ſent off through lateral branches of a much ſmaller orifice, till at length little more than the red blood alone remains to paſs through the evaneſcent artery into the incipient vein. But all theſe particulars, by which the blood is diſpoſed for the ſecretions, we ſhall conſider diſtinctly in the following chapter.

CHAP. VIII.

Of the SECRETIONS.

CLXXXVIII. THE claſſes or tribes of humours which, being depoſited or ſtrained off from the blood into other veſſels, are ſaid to be *ſecerned* or *ſecreted*, ſeem reducible to four : of which

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[66] The diverſity, in fact, is great of the fluids prepared in the bodies of animals, which is evident in their quantity, nature, and elements, production, uſe, ſucceſſion, and changes. The tears, ſaliva, mucus, fat, oil, ſweat and perſpiration, both external and in-

which the *firſt* includes all the viſcid and lymphatic juices, which are coagulated by a heat of about 150 degrees, by alcohol, and by acids; although generally, in the living animal, they are capable of flying off in form of a vapour, and after death are within the ſame veſſels

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internal, into the cavities and inteſtines; the urine, gaſtric and inteſtinal fluids; the bile, the lubricating liquor of the joints, the ſemen, the juice of the proſtate gland, the lymphatic juices, milk, chyle, and other liquors, whoſe nature is not yet ſufficiently known, as that in the gall-bladder, ſecreted from the cellules of the internal coat, and ſome others: In all theſe, that ſome agreement ſubſiſts, but in others the greateſt difference, is certain. But Haller's diviſion into four claſſes is not perfectly conſonant with truth; for more marks of difference are given, though I do not ſee the diſtinct limits. Chemiſtry ſhows certain particles in ſome, which others clearly want; there are however ſeveral chemical combinations ſo ſtrongly united, that the gentle actions in our body are ſcarcely conſiſtent with them. For the moſt part we ought not to truſt thoſe parts which we obtain by the operation of fire, and which are in our humours under clearly a different nature. However, chemiſtry has enabled us to reduce the animal humours into ſome certain claſſes. They ſeem capable of being divided into three; the pure, mixed, and dubious.

The firſt claſs contains clearly, (1.) Thoſe merely aqueous, and as if excrementitious, whoſe ſecretion is always copious; and they contain, along with a great quantity of water, ſome oil and ſanguineous exhalation, mixed with a little earth. Nature often wonderfully differs in the place of ſecretion, that almoſt always one may be ſubſtituted to the other with the greateſt ſafety to health; but they are often determined to the internal cavities, as in dropſy, to the great danger of life. To this chiefly belongs that part of the tears which ariſes from the exhaling veſſels, the urine, perſpiration, and ſweat. Theſe liquors never are ſecreted from true glands, but from the veſſels continued. (2.) The ſalivary liquors: With much water they join a ſaponaceous ſolvent principle; and although no pure mucus is mixed, they always ſhow ſome tenacity, and poſſeſs a wonderfully aſſimilating power: hence their primary uſe in the preparation and digeſtion of our aliment; but at the ſame time, the greateſt power of contaminating and infecting it, as in contagion, kiſſes, biting, &c. I refer to this the true ſaliva effuſed into the mouth, the pancreatic juice, the gaſtric and inteſtinal liquor. the part of the tears which comes from the lachrymal gland. Theſe are all ſecreted through true conglomerate glands furniſhed with an excretory duct. (3.) The mucus. Mucus is a very natural fluid, nowhere produced unleſs in the inner ſurface of the body, ſecreted from true follicles or cryptæ, forming veſſels compacted into a gelatinous thickneſs. To this claſs belong the vaporous juices of the ventricles of the brain, of the pericardium, pleura, peritoneum, vaginal

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forming mucus. It is made up of a leſs proportion of water than the preceding genera, with a pituitous, tenacious principle ductile into threads, which when dried leaves much earth. This phlegm is wonderfully increaſed and diminiſhed, according to the diverſity of climate, atmoſphere, aliments, drink, and way of life; and it is thrown out of the body to the great ſafety of the conſtitution, and at the ſame time ſerves for lubricating the various internal places and canals. The moſt remarkable of this kind are, the mucus of the noſtrils, fauces, aſpera arteria, alimentary canal, gall-bladder, urinary paſſages, vagina, and in part the liquor of the proſtate gland. (4.) The oily and ſebaceous: a ſpecies differing from all, ſecreted on the external ſurface of the body, for lubricating the ſame, and defending it againſt friction and the injuries from the air, depoſited from the blood in real cryptæ, or ſecreted through orifices or canals proper to the places for which it is deſtined. With a very ſmall proportion of water it unites a great deal of oil and inflammable principle, ſome volatile acrid matter, with a little earth. The liquors of this kind, however, differ in ſome places, according as they are mixed with various foreign ſubſtances. The wax of the ears has an agreement with the bitterneſs of the bile; the odorous glands of the penis and nymphæ mingle in their compoſition more volatile acrid matter than the fat. The primary ſpecies of this kind are, the oily matter on the hairy ſcalp of the head and face, the inteſtinal liquid of Meibomius, the wax of the ears, the viſcid ſubſtance about the areolæ of the mammæ, about the umbilicus, the oily emanation under the axillæ, in the groin, in the interſtices of the fingers of the hands and toes of the feet, the odoriferous glands under the preputium, and in the nymphæ, and in general upon the whole ſkin. (5.) The gelatinous coagulable liquors, which I call *lymphatic* by a better appellation. This gelatinous part of the blood the ſmalleſt arteries depoſite into various, not all, the cellular places of the body: it is found particularly betwixt the tunic and parenchyma of the bowels, under the integuments of the body and its cavities, in the very cellular ſubſtance of ſeveral of the viſcera, and in the ſyſtem of the lymphatic veſſels.

The ſecond claſs comprehends ſuch liquors as are manifeſtly compoſed of a different mixture alone of the liquors of the firſt claſs, and when mixed have in part ſomething proper. The tears iſſue from a double fountain: the milk conſiſts of the very chyle of the food, of ſome ſaliva, oil, and fat, and a good part of the lymph: the compoſition of the bile is a great quantity of the ſalivary vaginal tunic of the teſticle, of the amnios[67], joints, and probably of the womb, with the juice of the ſtomach and inteſtines, of the renal capſules, and laſtly the lymph itſelf commonly known and called by that name.

CLXXXIX. The *ſecond* claſs is thoſe of juices; of which ſome are exhalable, like the former (CLXXX.), but being more ſimple and aqueous, are neither to be coagulated by fire nor by rectified ſpirits of wine; and others do not exhale, but, being depoſited in their reſpective excretory ducts, are expelled by ſome common outlet, proper to a part of ſome gland. To the former of this claſs belongs the perſpirable matter of Sanctorius, part of the tears and watery humours of the eyes. To the latter of this claſs belong the remaining part of the tears, the ſaliva and pancreatic juice, that of the renal capſules, and the urine. The ſweat ſeems to be a mixture of the perſpirable matter and the ſubcutaneous oil.

CXC. The *third* claſs, differing from both the preceding, includes the viſcid, ſluggiſh, or ropy juices; but ſuch as are of a watery diſpoſition, and not congealable into a jelly, but hardening into a cruſt-like or ſcaly ſubſtance, by exhaling their water. Theſe

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ſalivary liquid, a good deal of oil, a little mucus, and a ſingular balſamic bitter and ſtimulating ſubſtance: the liquor in the joints is manifeſtly mixed with oil, lymph, and ſome part of a ſaponaceous liquor: the liquor of the proſtate gland is mixed with chyle, mucus, and lymph. We have not yet a complete knowledge of the nature of the ſemen, at leaſt it is not to be referred to the mucus ſolely; although, that it contains muccs of a very mixed nature, is ſufficiently demonſtrated from its peculiar and ſpecific ſmell, its gravity, and the animalcula it contains.

My third claſs comprehends ſome hypotheſes, moſtly referring to fluid bodies, whoſe nature and diſpoſition ſtill is a myſtery to us. To this head I refer the electric matter of animals, magnetiſm, nervous principle.

[67] As we do no find that nature of all coagulable liquors conſtant, their paſſing to a thick gelly, but are often found like aqueous ones; ſo it by no means univerſally holds of the liquor amnii: for by my own experiments I am certain, that it often evaporates like water, without any appearance of gelly.

do not effervefce with any falt, and are contracted and made thicker by acids. By lixivial falts they are diſſolved. By fire they are reſolved into water, a little volatile ſalt, and a little oil. Of this ſort is every kinds of *mucus* in the body, which we find ſpread through all the internal paſſages, whether deſtined for the tranſmiſſion of air, aliment, or urine, and the cavities above the parts of generation; to which ſort may be added alſo the ſemen.

CXCI. The *fourth* and laſt claſs is that of the inflammable juices, which at their firſt formation are indeed thin and watery, but, by time, ſtagnating and exhaling their more watery parts, become a thick, oily, inflammable liniment, often very bitter. To this claſs we refer the bile, ear-wax, ſebaceous and oily liniment of the ſkin, the marrow in the bones, and all the fat of whatever conſiſtence or in whatever part ſeated throughout the human body. To this claſs alſo belong caſtor and the yolk of an egg. And the milk itſelf, ſo far as it is butyraceous and inflammable, belongs to this claſs.

CXCII. Other humours, which we have deſcribed as ſimple, are compounded of the foregoing ones; as milk is compoſed of butter and water, and the liniment of the joints of lymph and fat.

CXCIII. Thoſe who conſider that in the blood are found a coagulating ſerum (CXXXVII.), an exhaling water (CXLII.), a ſort of viſcid mucus (CXXXVIII.), and laſtly an oil (CXLII.), may perceive the poſſibility to ſeparate from the blood all the foregoing claſſes (CLXXXVIII. to CXCI.) of humours; in as much as we thus ſee their conſtituent principles are already in the maſs of blood itſelf. But in what manner it is brought about, that oil is ſeparated from the blood in one part, a watery liquor in another, or a gummy mucus in a third, is a queſtion that ſtill remains to be explained, and requires a previous deſcription of the ſecretory organs themſelves.

CXCIV. The coagulable juices are ſeparated almoſt every where, from the arteries themſelves, into continuous excretory canals, without any intermediate organ or machine betwixt them. The proof of this we have from injections of fiſh-glue, water, and thin oils, which very readily paſs the red arteries, and are poured out like ſweat into all the cavities of the body, in which that coagulable vapour is naturally found; nor do the injections in this courſe meet with any intermediate knots or ſtops from any hollow cavities or cells. Finally, the blood itſelf, being ſo readily poured out into moſt of theſe cavities, without any permanent damage, when its courſe is either much obſtructed, retarded, or urged with a greater impetus through the arteries, ſhows plainly that there is a ſhort and open way betwixt the red blood-veſſels and thoſe excretory ducts.

CXCV. Another liquid, coagulable by acid ſpirits and alcohol, is the albuminous humour of the joints. This being compoſed of fat, medullary oil, and the exhaling liquor, conſtitutes an exceeding ſoft liniment, very fit for lubricating the cartilages, and leſſening the friction. For ſecreting this, there are appointed certain conglomerate glands of a peculiar ſtructure, which are ſituated in the articulations of the bones, ſo that they may be moderately compreſſed, but cannot be cruſhed.

CXCVI. The ſtructure of theſe glands is peculiar to themſelves. The larger cluſters of glandular kernels adhere, for the moſt part, to the bone, by a broad baſis wrapped up in fat. From thence, being drawn out into a kind of creſted edge, they pour out their liquor from an exceedingly thin border, by open ducts, which however I do not find very evident. Other leſſer ones, placed every where in the capſules of the tendons, and between the diverging fibres of the ligamentary capſules of the joints, ſeem to be much of the nature of ſimple glands, and are turgid with yellow mucous ſerum.

CXCVII. The uncoagulable juices (CLXXXIX.)

of the firſt ſort are ſecreted in the ſame manner with thoſe which harden (CLXXXVIII.); to wit, from the exhaling arteries, which ariſe from the red ſanguineous arteries, without any intermediate follicle or cavity betwixt them. Thus the veſſels, which pour out the perſpirable matter through the ſkin and lachrymal ducts of the firſt ſort, ſuffer a watery or thin gluey injection to tranſude ſo readily from the arteries, as leaves no room to doubt of this truth. And theſe ſecretory ducts have alſo a conſiderable degree of irritability; whence, by any ſtimulus or contact of acrid particles, they diſcharge more juice in a given time than what they diſtil in a ſtate of health.

CXCVIII. But in the latter ſalival kind of that claſs, the ſecretion is made by means of *conglomerate* glandules, which the ancients ſo called from their cluſter-like fabric, and eſteemed almoſt the only proper glands. Theſe are compoſed of roundiſh lobules or cluſters (ſomewhat like thoſe in bunches of grapes, currants, barberries, &c.) looſely conjoined together into larger maſſes by the yielding cellular ſubſtance, which, at laſt, often forms a denſer coat or covering to the whole, ſuch as we ſee in the parotid and maxillary glandules. Through the intervals betwixt theſe glandular cluſters or grape-like bunches, run the arteres and veins, which are here large or conſiderable enough. But moſt of the conglomerate glandules ſeparate their juices in ſuch a manner from the blood, and from thence diſcharge it ſo, that each kernel ſends out an excretory duct; which, joining with others of the ſame kind, form larger trunks, which at laſt, in the manner of a vein, end in one canal, which conveys the humour, ſeparated by the gland, to the part for which it is deſigned, as the cavity of the mouth, inteſtines, ſurface of the eyes, &c. There are, indeed, ſome of theſe glands in which the ſaid excretory ducts are either not preſent, or at leaſt not yet diſcovered; as we obſerve in the thyroideal glandules, thoſe called *capſulæ renales*, and the thymus; unleſs we ſuppoſe theſe to approach to the nature of conglobate glands[68].

CXCIX. The *acini* or kernels of theſe conglomerate glands are each of them circumſcribed and limited by a harder ſtratum of the cellular ſubſtance; by which ſubſtance they are alſo ſubdivided into leſs acinuli,

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[68] All phyſiologiſts and anatomiſts talk of the glands, as bodies which, by reaſon of a peculiar fabric ſuited to their functions, differ from the other parts of the body, as arteries, nerves, muſcles, bones, &c.; and for the greateſt part are endowed with the faculty of ſecreting. Under this name of gland come many bodies, though they are infinitely different: but you every where find the utmoſt confuſion, an illicit commixture of organs, which it is evident ſhould be ſeparated from each other; and ſo great an uncertainty in the deſcription of things, that unleſs you ſeparate the true from the falſe, the probable from the improbable, you ſcarcely know what really deſerves the name of gland. For nobody will be ſo ignorant of anatomy, who, if he conſiders all theſe things with a ſmall degree of attention, will not immediately ſee, that the name of glands is received in the moſt ample ſenſe. It is evident, that the mammæ, furniſhed with true glands, diſtinct papillæ, and real excretory ducts, in which they convey a certain liquid to the ſurface of the body, have little relation to the glandula thyroidea, deſtitute of papillæ, excretory duct, and liquor; nevertheleſs the name of gland has been conferred upon that ſame body equally as upon this laſt.

Indeed ſeveral authors of later times have agreed, that in glands there is a natural difference, as they ſay; ſo that they conſtitute one claſs of conglobate, and the other of conglomerate; to the former, referring thoſe bodies of glands in which no diſtinct papillæ appear; to the latter, thoſe which are furniſhed with real papillæ. But that diſtinction ſeems to me to come nearer nature, if the glands are ranked, according to the function of ſecreting, to conſtitute two claſſes; one of which comprehends the whole ſeries of glands, ſecreting a true and known liquor; the other contains the genera and ſpecies of the glands, whoſe liquor and mechaniſm of ſecretion is either not ſufficiently clear, or only fictitious.

Into the firſt claſs, therefore, deſerve to be placed all the true ſalival glands or other conglomerate ones; as the parotid, maxillary, lingual, lachrymal, thoſe of the cheek, mammary, the pancreas, Brunner's, and Peyer's ones of the inteſtines, Havers's ones of the joints, and an infinite number of cutaneous ones: For it is common to all theſe, the ſeries gradually diminiſhing, to be formed from leſs portions; the leaſt of which, marked by the name of *papillæ*, ſcarce acinuli, as is evident to the eye and by the microſcope. But it may be queſtioned, How does this ſubdiviſion end? Whether or no is every ſimple acinus or kernel hollow in its middle, that by receiving the humour tranſuding from the arteries into the follicle or cell, it may be ſent out thence by the excretory duct? Whether or no are we perſuaded to believe ſuch a fabric obtains from the ſmall ſhot-like ſtones and hydatides bred in theſe glands with the round ſcirrhi that ſometimes fill the kidneys? Whether are the larger viſcera, appointed for the ſecretion, of the nature of conglomerated glands? Whether is this opinion made probable from the morbid round concretions formed in the liver, ſpleen, kidneys, teſticles, and cortex of the brain; or from the bunch-like diviſion or appearance which thoſe viſcera have in younger animals? Whether the cellular ſubſtance, that ſurrounds the extreme vaſcules in all parts, does not communicate by open areolæ or cells, in which a ſecreted humour is poured by theſe glandules?

CC. In ſhort, none of theſe arguments appear true or concluſive. For the acini, which are found in the viſcera of brute animals, are component lobules, and not elementary parts; but are large and compounded for the conveniency of each beaſt. The morbid con-

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ſcarce viſible however, conſiſt of cellular ſubſtance, which comprehends arteries, veins, and an excretory duct, with an intermediate follicle or cavity. Theſe excretory ducts either open into a cavity with a ſmall mouth, as in the inteſtines or ſkin itſelf; or run into a greater duct, as they ſeek an iſſue in moſt of the ſalival ones, or ſeveral greater or leſs ones, as in the mammæ and ſublingual ones. By theſe marks, the true ſecreting glands, on the one part, may be diſtinguiſhed from the non-ſecreting; and on the other part, from the ſecreting viſcera, the liver, kidney, and teſticle.

The ſecond claſs comprehends a multiplicity of different parts, viz. the comprehenſive and ample ſeries of lymphatic glands; Pacchion's corpuſcles in the dura mater, not yet ſufficiently underſtood; the pinealis and pituitaria in the brain, unjuſtly called glands; the thyroid in the neck; the thymus in the breaſt; the capſulæ renales in the abdomen, &c. The proſtate, I think, as it gives out a true liquor, ſhould be ranked among the viſcera, rather than among the glands.

concretions are almoſt all of them a ſort of placentulæ, formed in the loculi of the cellular ſubſtance, and take up their ſeat even in the limbs themſelves, where there is not the leaſt room to ſuſpect any thing of a glandular fabric; and are compoſed, as to their matter, of oil, earth, and vaporous particles, extravaſated into ſome of the leaſt interſtices of the cellular ſubſtance, where, ſtagnating and compreſſing the adjacent follicles, they form to themſelves proper membranous tunics. On the contrary, the watery and fluid nature of the juice ſecreted in theſe glands (CLXXXIX.) is an argument that it meets with no arreſtment in the ſeparation, nor places of ſtagnation in its way. For all the juices that reſt any time in the warm cavities of the human body, which are full of abſorbing veſſels, are each of them more or leſs inſpiſſated, and approach either towards a mucous or an oily diſpoſition. Moreover, if there were any ſuch arreſtments, anatomical injections would meet with more difficulty in paſſing from the arteries into the excretory ducts of thoſe glands; which, under ſuch circumſtances, would be impervious to thick injections, and thin ones they would exhale into their cellular fabric. Yet we ſee that the ſuperlative art of great anatomiſts has not only conveyed injections, but even thick ones like wax, directly from the arteries of the ſalival glands, liver, &c. into their excretory ducts; and this without filling up any intermediate knot-like cavities, which, according to the foregoing hypotheſis (CXCIX.), ſhould be the caſe.

CCI. Therefore the *acini* or kernels of theſe glandules appear compoſed merely of arteries and veins divided and ſubdivided, parted and connected, by the intervention of a good deal of cellular ſubſtance, whoſe ſtrata growing gradually more compact or firm as they enlarge, at length ſhow their contents moulded into a ſort of globular nut-like figure. In the belief of this, we are confirmed by analogy in the lobes of the lungs, the lobules of the thymus, and from the ſtructure of inſects; but more eſpecially the fabric of the teſticle, in which we plainly ſee, that the lobules are formed of excretory ducts, connected together in faſciculi by a very ſoft membrane. But they ſeem not to pour their juices into a cellular fabric, which would intercept or make difficult the paſſage to an excretory duct. The late experiments alſo of very eminent anatomiſts have ſhown very ſmall, white, cylindric veſſels, to be the real elements of the viſcera; and it is to be hoped that this diſcovery will be confirmed by future obſervations.

CCII. Thin watery juices, neither coagulable nor wholly evaporating, are likewiſe in other parts generated without the aſſiſtance of conglomerate or kernel-like glandules. For thus the urine is depoſited from the red or ſanguinous arteries into membranous pipes, with which they are manifeſtly continuous, and form an eaſy way, admitting air, water, and mercury, to paſs in like manner. And after the ſame manner, though leſs evidently, the nervous juice ſeems to be ſeparated in the brain.

CCIII. The third claſs, or *mucous* juices (CXC.) are indeed almoſt every where ſeparated into, and diſcharged from, ſinuſes or hollow glands[69]. Theſe true glands or follicles have, in general, ſuch a fabric as makes up an ample cavity, every where circumſcribed by a membrane; but in ſuch a manner, that the fleſh itſelf of the part to which the gland adheres is often taken for another cloſe hemiſphere of the follicle. The ſaid cavity or follicle is generally round; but ſometimes it is oblong, and obliquely ly creeping betwixt the adjacent parts; as, for example, in the urethra of the male, and in the follicles of the ſinus muliebris. They are irritable; and when ſtimulated by acrid ſubſtances, increaſe the quantity of their ſecretions.

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[69] Many anatomiſts, and thoſe even of great note, often confound the words *glands* and *follicles*; ſo that ſpeaking of glands; they call them *follicles*, but when they talk of follicles, they call them *glands*; between which bodies, however, a great difference ſubſiſts. Folliculus and crypta is almoſt one and the ſame part, to wit, it denotes a membranous cavity, conſiſting of one or ſeveral places of retirement, into which the veſſels depoſite a liquor, remaining a longer or ſhorter ſpace in it, ready to be excreted for the moſt part by a mouth or even a canal. I would wiſh to uſe this word *follicle*, when we ſpeak of mucous liquors; and *cryptæ*, when we ſpeak of oily or ſebaceous liquors.

CCIV. Into theſe follicles or cells the leaſt arteries (or the vaſcular fleſh ſurrounding each crypta or cell, and completing its convexity) open by producted extremities within the cavity of each crypta, into which they diſtil or exhale their reſpective juice; where, being retained from the narrowneſs of the excretory duct, the more watery parts are drawn up by the abſorbing veins, which correſpond to and reſemble the exhaling arteries; and thus the follicular juices receive a conſiderable degree of thickneſs. The truth of this we are taught from the ſtructure of the ſimple follicles obſervable in the tongue, in which both the importing arterial ducts or pores, and likewiſe the excretory mouths, are viſible to the eye; and from the velvet-like tubuli lining the ſtomach of birds, in which a ſecretory villoſity manifeſtly hangs in the cavity; and laſtly, from injections which diſcharge a colourleſs wax into the ſimple glands[70].

CCV. Whether the mucous cavity of ſuch a glandule be long or round, it has always an excretory duct, which for the moſt part is none of the leaſt; altho', in the round mucous glandules, the diſcharging duct or orifice be leſs, in reſpect to the reſerving cavity, than in others. This diſcharging orifice often opens into the common large cavity, into which the mucus is to be poured, without any intermediate duct; for thus it is in the back of the tongue, and in the ſimple glands of the ſtomach and inteſtines, where they have been denominated *cryptæ* or cells by Ruyſch. The ſinuſes have often the like fabric opening without an intervening duct, as in the urethra of the male.

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[70] By metaſtaſis nature depoſites in diſeaſes a foreign matter in theſe follicles, as we ſee in the ſmall-pox found in the noſtrils, larynx, aſpera arteria, and inteſtines.

CCVI. Another kind of theſe glandules is, where ſimple follicles are folded up together in one common covering, and open with their gaping orifices into one common ſinus, without forming any true excretory duct. This fabric we obſerve in the tonſils.—Theſe are called *conglutinated* glands.

CCVII. Other ſimple glands of this claſs have an *excretory duct*, by which they expel their mucus; namely, a narrow, membranous, cylindric, ſmall veſſel, opening with its poſterior orifice into the cavity of the glandule, and with its anterior orifice opening into the common cavity, for which its mucus is deſigned. Theſe excretory ducts are of conſiderable length in the ſubcutaneous and ſebaceous glands, and in thoſe of the palate and wind-pipe. In ſome parts alſo, the pore or orifice, and its duct, are more eaſily demonſtrable than the follicle or body of the gland itſelf; as in the noſtrils, larynx, rectum, &c

CCVIII. In others, again, an aſſemblage of theſe ducts, ariſing each from its reſpective follicle, run together into one like the branches of a vein, ſo as to form a conſiderable excretory canal, common to a number of follicles. To this kind belong the compound mucous glands of the inteſtines, ſome of the larger in the cavity of the urethra, with the blind or impervious duct or ſinus at the root of the tongue; to which, in brutes and birds, add the fringe-like tubuli of the ſtomach. The glands of this ſort may be called *ſimple ones compounded or continuous:* but where they lie only contiguous one to another, they may be called *ſimple aggregate* or congregated glandules; as are thoſe of the fauces, ſtomach, inteſtines, &c.

CCIX. The inflammable juices (CXCVI.) are ſeparated by organs differing in their fabric. The fat and marrow are depoſited without the intervention of glands, from the ſmall mouths of the leaſt arteries into the cellular coat or rather ſubſtance; and the ſame fat again eſcapes from under the ſkin by ſmall pores or ducts, without the aſſiſtance of any glandular follicles. But the ear-wax, and the waxen or ſuety liniment of the ſkin, are ſeparated by glands of divers kinds. Moſt of the ſebaceous glandules are viſible enough, with an open or naked mouth in the ſkin, that leads immediately into the follicle, without any duct of conſiderable length; as we ſee in the external ears, noſe, rings about the nipples, in the female nymphæ, and the valley or groove that runs betwixt them and the external labia, in the clitoris, and in the male glans and prepuce. Theſe differ but little from the cryptæ (CCV.) except in their contained matter, which they ſeparate.

CCX. There are others of the ſebaceous glands, which have an excretory duct of a conſiderable length, like moſt of thoſe in the ſkin; which, being ſeated in the cellular ſubſtance, have conſequently a duct long enough to perforate the ſkin Thus we ſee it moſt evident in the face, where the length of the duct is often to be meaſured by the concreted maggot-like ſubſtance preſſed out; the bulk of which demonſtrates, that a follicle or cell lies under the narrower pore.

CCXI. There are ſtill other ſebaceous glands of the kind mentioned CCVIII. in which many cryptæ by ſmall ducts meet together in one larger excretory duct. Thus in the face, in ſeveral places, there are large pores in common to a number of ſubjacent cryptæ. And of this kind are thoſe ſebaceous ſinks or little inteſtines in the eye-lids: and thus it is in the ſecretory organs of the muſk goat, beaver, hyæna, civet-cat, and muſk-rat, which gather their ſebaceous matter into one common receptacle.

CCXII. The milk, being a humour of its own particular kind, formed of oil and watery juices intermixed, is ſeparated by conglomerated glandules whoſe fabric we deſcribed at CXCVIII. Whether the ſecretion of the bile be glandular, is controverted; but there are many arguments to perſuade us, that the liver is a mere vaſcular fabric, whence the bile diſtils immediately from the extremities of the porta into the *pori biliarii*, or roots of the biliary ducts, without paſſing any cells or follicles by the way: and in this we are more eſpecially confirmed by the Ruyſchian art of injection, in which the wax paſſes directly from the porta into the biliary ducts, without exhibiting any intermediate knots or ſtoppages; and therefore we ſee the milk and bile are both of them much thinner and more watery than the fat, or the ſebaceous matter which thickens in follicles.

CCXIII. It now remains for us to inquire, how, from one common maſs of the blood, the ſame variety of peculiar juices are conſtantly ſeparated each in its reſpective place; ſo that we never ſee milk ſecreted in the kidneys, bile in the thymus, or mucus in the ſebaceous glandules. This problem will not be ſolved, till we ſhall have previouſly acquired a thorough knowledge of the intrinſic fabric that obtains in each ſecretory organ. In the mean time we ſhall here propoſe what has been hitherto advanced with certainty on the ſubject.

CCXIV. Now, firſt, the blood itſelf, from whence any liquid is to be ſecreted, in the various parts puts on ſuch a character or diſpoſition there peculiar to itſelf, that more particles of a like nature with the humour abound in that portion of the blood, which *nature* intends to ſeparate from it. In the liver, the venous blood arrives with a very ſlow motion, full of oil, and full of the ſemiputrid vapours of the inteſtines. To the teſticles, the blood is brought ſlowly through very long ſlender and inflected canals, ariſing at very ſmall angles, and paſſing out of the abdomen through a cold tract under the ſkin. In the carotids, it is probable that the ſtronger, ſpirituous, and denſe parts of the blood aſcend; while whatever is more watery deſcends into the abdomen and to the kidneys; alſo to the forming of the ſalival juice of the pancreas, and the liquor of the ſtomach and inteſtines.

CCXV. Another preparation of the blood, towards ſecretion, is from its retardation in the leaſt veſſels: whereby the red and denſer parts go on by themſelves along the axis of the canal; while the other lighter and more ſluggiſh particles, going on with a leſs velocity, recede to the lateral openings or branches, ſo as to enter the ſecretory orifices, which paſs out from the ſides of the ſaid veſſels; and to theſe they adhere by their viſcoſity.

CCXVI. Theſe orifices, though of different diameters, are yet always ſmall enough, in their healthy and natural ſtate, to refuſe the red blood. Hence, therefore, we may conclude, that, being enlarged by an increaſed force of the heart, they every where admit a good deal of the red blood from the ſanguineous artery, which they ariſe from and open into, as we cannot with probability ſuppoſe them to be much leſs than the red globules: And hence the ſame ſecretory orifices or ducts, which refuſe thick injections of wax or ſuet, do nevertheleſs generally admit thinner liquors injected into the arteries. Therefore this is the firſt and moſt ſimple mechaniſm of ſecretion; viz. that the light or opening of the excretory duct may admit only ſuch particles as have their greateſt diameter leſs than the diameter of the ſaid opening. From this reaſon only it is, that the yellow arteries convey a pure liquor from the blood, and that the uriniferous ducts exclude both the red blood and coagulable ſerum. But this is not the ſole cauſe, ſince the ſame juices are generated by large as by ſmall animals.

CCXVII. Merely by this law, the ſecreted juices may be of many different ſorts: for thoſe whoſe lights or tranſverſe ſections are the leaſt will receive only the thinneſt juices, as in the ſmall veſſels of the brain; and the largeſt ducts will admit water and jelly, while the thickeſt fat will enter the biggeſt of all. Moreover, if a number of ſecretory organs are formed in a ſucceſſion from one ſecerning artery, each of them having large mouths or ducts; in that caſe, the laſt which come out from the ſaid artery will receive only the thinneſt juices. But if thoſe which are firſt formed in order from the ſecerning artery, have ſmaller ducts, then the laſt only will receive the groſſeſt juices. It may be objected, that though the veſſels in a fœtus are vaſtly leſs than in adult, yet the humours are the ſame. But thoſe humours which are called fat, bile, lymph, and urine in the fœtus, are vaſtly different from the fat, bile, lymph, and water, of a man.

CCXVIII. From hence only it is that the ſecretions are generally made immediately from ſanguineous arteries without paſſing the ſerous lateral ones, (XLV.) Theſe all ſeparate groſs juices; thick, coagulable, or watery; as the fat, urine, juice of the ſtomach and inteſtines, &c. But the ſecretions of the other thinner juices are made not from ſanguineous, but from ſmaller pellucid arteries ariſing from the former; to the ſecerning mouths of which, not only no red blood, but no ſerum, fat, or other groſs juices, can have admittance. Thus the more thin and pure humours muſt neceſſarily be ſeparated; as for example, in the eye.

CCXIX. Perhaps *the angle*, which the ſecretory branch intercepts with its trunk, contributes ſomething to ſecretion. For it is eaſily demonſtrated, that at right and retrograde angles, only the viſcid and ſluggiſh juices are expelled by the ſtronger force of the particles keeping the middle of the canal; but the liquids which are about to go off at half right angles, are thoſe which preſerve their velocity. For, in living animals, the velocity of the blood is greateſt in veſſels of the acuteſt angles, and leſs in thoſe of right angles, as men of veracity have obſerved. That the effect of theſe angles in the veſſels is conſiderable, with regard to the ſecretion, we are perſuaded from the ſtructure of the body itſelf; ſince they form different angles in different parts with reſpect to their trunks, and in ſome parts compoſe net-works. For the ſmalleſt veſſels, in general, reſemble the branchings of little trees or ſhrubs, the trunks and arms of them every way ſending out branches, but in different angles; ſmall in the large inteſtines, but larger in the ſmaller inteſtines. Thus, in the ſpleen, the ſmaller red arteries ariſe ſo thick from their trunks, that they reſemble a wiſp or ſprinkler; in the inteſtines, they reſemble pencil-bruſhes; ſerpents, in the kidneys; ſtars, in the liver; a radiated circle in the uvea; and in the teſticle a lock of hair curled up into a button. But we very properly preſume, that the Creator never made this diverſity of fabric for no purpoſe. We have not as yet, however, any account of theſe net-works that can be ſufficiently depended upon. Neither does there ſeem to be any affinity between the fabric of the veſſel and the nature of the liquor which it ſecretes: and, indeed, theſe net-works are almoſt ſimilar to the veins, as if made rather for ſhortening the paſſage of the blood in ſome meaſure, than for diverſifying the nature of the ſecretion.

CCXX. The *inflexions* of the ſmaller veſſels, as well arteries as excretory ducts, greatly retard the motion of the blood; in which, therefore, the greater part of the force received from the heart is evidently ſpent in changing the figure of the veſſels. The repeated inflexions, therefore, of the ſecretory arteries increaſe the viſcidity of the juice, by delaying the flux, and giving the parts more time to cohere or attract each other. But a ſtraight courſe of the veſſels increaſes the celerity of their fluid, whence a copious and eaſy ſecretion; but then it makes the ſecretion more impure, as we ſee in the urine.

CCXXI. That the ſmaller arteries have different *degrees of denſity* or firmneſs, there is no reaſon to doubt; ſince we actually find it ſo by experiments in the larger branches. But the denſer the capillary arteries, the more they reſiſt the light and ſlowly moving particles, and yield only to the more denſe ones that have a greater impetus. Irritability produces almoſt the ſame effects; for if the ſecretory ſtrainer has a very acute ſenſation, it will reject the groſs humours, and tranſmit the more fluid ones: inſtead of mucus in the urethra, it will ſeparate a thin yellow ſerum; and almoſt the ſame matter, inſtead of the ſebaceous matter that lies under the ſkin: the quantity of ſecreted liquor will alſo be increaſed; as for example, in the tears.

CCXXII. Again, the velocity is greatly increaſed, if the heart is near; if the artery is ſtraight, or if it is produced with a ſmall angle; alſo, when the excretory duct ariſes before the extremity of a larger arterial branch: and it is diminiſhed, when the ſmall ſecretory artery runs a long way capillary, whereby the blood loſes the greater part of its motion in friction. Finally, from whatever cauſe the diverſity may ariſe, a greater velocity increaſes the quantity of ſecreted liquor, and produces heavy, more groſs, impure liquids; it alſo gives a degree of fluidity to the ſecreted liquors, as it prevents the ſtagnation, by which they might contract a viſcoſity: but ſlowneſs increaſes the attraction and viſcidity, and renders the ſecreted juice more pure; as the ſimilar particles when brought together can better attract and join each other under a ſlow motion, ſo as to follow the courſe of the larger canal, while the thinner parts go off by the leſſer lateral branches. From hence it is, that, only the impulſe of the heart being too much increaſed, all the ſecretions are confuſed.

CCXXIII. Theſe conditions nature is able variouſly to join together or ſeparate, and impart to every ſtrainer in greater or leſſer degrees; and thus by various methods to modify the ſecreted humours. Anatomy furniſhes an example, if you compare the ſtrainer of the bile or ſemen, which are thick juices, with the ſtrainer of the urine and tears, which are fluid ones[71].

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[71] The difficulties attending the explication of animal ſecretion, no mortal, perhaps, will ever unravel: content we muſt be, if obſervation, in ſo manifold a confuſion of conjectures, ſhall impart a little light to the ſubject. Some phenomena undoubtedly are obſerved, which prove, that there is between certain bodies a certain mutual re-

CCXXIV. From all that has been hitherto advanced, we may now begin to perceive, that ſince the blood contains particles of various kinds; ſome ſluggiſh; others mucous; others coagulable, but fluid; ſome denſe and red; ſome watery and thin; others fat and groſs (CLXXXVIII. *et ſeq.*): among all theſe particles, thoſe which are the largeſt and moſt denſe, as the cruor, will go on moſt towards the axis of the veſſel, ſo as to paſs on in a continued courſe from the artery into the trunk of the ſanguineous vein (XXXIX.)

CCXXV. Thoſe particles which are groſs and ſluggiſh, as the fat, muſt needs go off laterally by larger orifices from the ſanguineous artery, by ſhort ducts; for long ducts would make a ſtop to ſuch a ſluggiſh juice as oil. The phenomena of the adipoſe ſecretion (XIX.) agree with this deſcription. Such parts as are coagulable, but ſpecifically heavier than thoſe which are merely watery, kept fluid only while the powers of liſe are in action; theſe paſs off laterally from the red arteries, into the arteries which are not red, but continuous to the red ones, and ſmaller; whether theſe pellucid ones are continued on in the nature of trunks, ſending off other ſmaller branches, like the leaſt arteries (XLI); or whether they exhale their contents by a ſhort extremity, like the veſſels of CLXX.

CCXXVI. Thin watery juices may evidently paſs
off

relation of uniting, and a power of converting, ſome particles, whoſe nature is very variable, into their own. The former ſhows attraction, the latter aſſimilation, but both as an effect. How many viſcera and other parts in the body, totally different in nature, if loſt, are formed and reſtored by the moſt ſimple aliment! What a variety of plants in one and the ſame native place grows and thrives with nouriſhment not at all different in quality? Upon conſidering the wonderful effects of putrefaction, contagions, and ulcers, who would doubt, that theſe changes are owing to the power of aſſimilation alone? Not, therefore, without great probability may we aſſert, that there is in the animal body a certain aſſimilating agent, which, in the ſecretory organs, gives the particles procured from the common ſtore-houſe of the blood, their own proper quality, though before of a far different nature.

off by any veſſels continuous with the ſanguineous ones, or the leſſer ones (XLIV.), provided they be only ſmall enough to refuſe the groſſer juices: and this, whether they come out from the ſides of the larger arteries; or whether by a long continued courſe, and ſending off all the groſſer juices by large lateral branches, they, at length, end in a ſmaller pellucid canal inſtead of a trunk; as for example, in the eye. To the production of theſe juices, the moſt ſimple fabric is ſufficient; even a direct continuation of the ſcretory artery itſelf into an excretory duct, as we ſee in the urine. Therefore, the ducts and veſſels have here a ſtraight and ſimple courſe, with few or no inflexions; and a proportionable velocity ſtill holds in the courſe of their contained juices. Such juices as, being watery, light, but viſcid at the ſame time, are conſequently ſluggiſh and leſs moveable; theſe may be eaſily ſecreted by ſhort narrow ducts of a leſs diameter than to admit the fat, and appended to the ſanguineous arteries: and, therefore, it is evident, theſe will be ſeparated from the blood more abundantly in ſome parts of the body than others; namely, where the velocity received from the heart's impulſe is leſs, the flexures of the artery more frequent, and where the extent of the capillary artery ſhall be carried to a greater length.

CCXXVII. Whether or no ought we to aſcribe to each particular part, the ferments, pores, ſpecific weights, or filters filled with their own peculiar humour, and admitting nothing that is analagous to it, which determine the nature of the humours to be generated? One who admits of theſe, ought to conſider the great difference there is in one and the ſame juice, ſeparated in the ſame part of the body, according to the difference of age, courſe of life, &c. The bile in a fœtus is generated ſweet; the ſemen thin, and without vermicles; the milk either none or watery; the urine watery, mucous, and inſipid; the uterine mucus very white; the cutaneous veſſels full of red juices;

the watery juices reddiſh; and the fat gelatinous. By the ſame organs, in an adult perſon, the bile ſeparated is ſharp or acrid; the ſemen thick; the milk butyraceous; the urine yellow, thin, and alkaleſcent; the womb diſcharges a menſtrual blood, and the aqueous humour is very clear. But, even in the adult perſon, how different is the urine? at one time watery; at another, thick or concocted; in a fever, heavier, full of ſalts and oils. The paſſions of the mind, which make no other change in the body than that of ſtrictures in the nerves, yet wonderfully change the ſecretions, and expel even the blood and bile through the veſſels of the ſkin. Add to this, the frequent diſturbance of the ſecretions, and the changes to which they are liable from ſlight cauſes; ſo that only an increaſed celerity ſhall cauſe ſeveral differing liquors to be ſecreted by one and the ſame organ: for blood has been known to paſs into almoſt all the paſſages of the ſecreted juices; into thoſe of the ſweat, tears, mucus of the noſtrils and of the womb; and into the lactiferous, ſeminal, and urinary ducts, as well as the fat. A true milk has been ſeen ſeparated by glands in the thigh. When the urine has not been excreted by its natural courſe through ſome defect of the kidneys, ureters, or bladder [72], it has paſſed by the ſkin, exhaled into the ventricles of the brain, or even into the whole cellular fabric. The perſpirable matter of Sanctorius, however thin, is often by cold driven to the kidneys; or, by fear, or medicines, determined to the excretory villi of the inteſtines. That exhaling viſcid juice is ſecreted by the ſame organ with the fat, from which it ſo much differs, into the celular ſubſtance, is re-abſorbed, and alternates again with the ſame, (XVIII. &c.) A ſalivation ſupplies the place of the Sanctorian or cutaneous exhalation externally, and of the cuticular exhalation internally. The bile, reabſorbed, evidently appears flowing in the veſſels of the eyes. Nor does there appear any thing in the fabric of any of the viſcera or glandules that can fix or maintain the nature of the ſecerned fluid. The ſpecific gravities of the viſcera and ſtrainers neither anſwer, according to the authors who treat of them, to the ſpecific gravity of the humours which they ſecrete; nor are they at all known by experiments that can be depended on.

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[72] A preternatural increaſe or hardneſs of the proſtate gland is here meant; which ſo compreſſes the neck of the urethra, as to prevent the tranſmiſſion of a ſingle drop of urine. I ſaw a caſe of this kind in a perſon of 70 years of age, who died of a ſuppreſſion of urine in the ſpace of ten days. Beſides the unuſual expanſion of the bladder, which contained ſix pounds of water, all the parts of the body emitted a urinous ſmell, the brain not excepted; in whoſe ventricles, as alſo in the pericardium, ſo great a fetor was perceptible to the byſtanders, that they compared it to that of a chamberpot. Another memorable example of the urine determined to other places, when its excretion is impeded, occurred in the winter of 1778. I diſſected a ſubject, who wanted moſt evidently one kidney, and veſſels, and ureter; the other was of a little ſize, and the bladder ſmall. All who knew her fled from her as from a ſerpent; even her own huſband left her; becauſe on account of the intolerable urinous ſtench they could not endure her company.

CCXXVIII. It now remains for us to diſcover, how the ſecretions, in a healthy perſon, become pure or uniform. For all the juices that have been lately ſecreted (without excepting any, even the oil or fat itſelf) have a great many watery particles intermixed; ſo that none of the thicker juices ſeem capable of being formed without having a mixture of the thiner watery ones: how then do the ſemen, bile, fat, mucus, and other thick juices, deprived of their ſuperabundant water, acquire their viſcidity and other qualities?

CCXXIX. For this end, nature has framed glands, with large and ſmall follicles or reſervoirs, for retaining the ſecerned juices, from which the watery parts are required to be ſeparated, to render the remaining part more ſtrong and viſcid. The mucus, at its firſt depoſition, is thin and watery, little differing from the perſpirable vapours or tears; in which ſtate it diſtils into the cavity of the noſtrils, wind-pipe, and in-

inteſtines. This is not continually diſcharging, becauſe the excretory orifice is narrow (CXCVI.); and the excretory duct being ſometimes long and ſlender, at other times repeatedly bent and winding, or tranſmitted through a hard cellular texture, or cloſed by ſome force equivalent to a ſphincter, ſo retards the juice, that it cannot paſs out without preſſure; or perhaps, not without being irritated by the quantity or acrimony of the juice, the follicle preſſes out the liquor, which incommodes it, by a kind of periſtaltic motion. This appears from the morning diſcharges of mucus by blowing the noſe, coughing up from the lungs, and by ſneezing after the nocturnal ſtagnation. In the mean time, the veins, extended into the cavity of the follicle, and ſpreading in every direction, abſorb the more aqueous parts from the thin mucus, that it may become thicker the longer it is retained; but if, by the force of ſome ſtimulus, it be directly diſcharged after it is ſecreted, it comes out thin and watery. Examples of this we have in the urethra, in the noſtrils, and in the ear-wax; as alſo in the bile, which, at its firſt ſeparation in the liver, is watery, and has but little yellowneſs or bitterneſs. It is, therefore, retained by a large follicle or gall-bladder; and there digeſted or exalted by the vital heat, and its more thin or watery parts exhaled or abſorbed by the veins; whence the remainder becomes more thick, bitter, and oily. The ſame mechaniſm takes place in regard to the ſemen; which, being reſerved in the ſeminal veſicle, is there thickened, ſo as to be very viſcid after long chaſtity; but in repeated venery it is expelled very fluid. In ſome places nature has made theſe receptacles two or three times folded together in one and the ſame organ, when her deſign was to form a very thick juice. Thus the ſeminal paſſage is in the teſticles reticular; in the end of the epididymis, one large canal ending in a larger veſicle: the veſſels of the teſticle are narrow, and ſo are the vas deferens and proſtatic duct. Hence there are nowhere real glandules, except for ſecreting a viſcid liquor. And if a viſcid liquor has been ſeparated from the arteries without a follicle, it always ſtagnates in a large follicle. The ſemen, bile, liquor of the joints and fat, afford examples of this.

CCXXX. A ſecerned juice may be likewiſe changed in its receptacle by the affuſion of ſome new liquor. Thus the ſemen thickens by an affuſion of the proſtatic liquor; the chyle is thinned by mixture with the ſaliva and pancreatic juice, and that which diſtils from the villi of the ſtomach and inteſtines, and by an affuſion of the bile it becomes alkaleſcent; and again the ſynovia or albumen of the joints is tempered by the two kinds of fat (CXCV.)

CCXXXI. Laſtly, whatever is abſorbed, can be of uſe to the animal according to its nature, after it is taken into the blood; as the ſemen gives a ſurpriſing ſtrength to male animals. For the moſt part, likewiſe, when a humour is long retained, a lixivial acrimony is generated, not without its own uſe, in the bile and ſemen.

CCXXXII. But the great uſe of the follicles and receptacles of glands is to preſerve the juice, of whatever kind it be, for thoſe times, in which it is moſt neceſſary to be employed in the actions of life. Thus the bile is reſerved for the time of digeſtion, the ſemen for due venery, and the mucus of the noſe is accumulated in the night to temperate the irritation of the refluent air in the day.

CCXXXIII. Therefore, as nature has in this way framed machines, by which the juices are retarded in the large and ſmall follicles; ſo ſhe has made others to expel them at ſuch convenient times. To ſome glands ſhe has given particular muſcles for this uſe; as in the teſticles of brutes, the urinary bladder, and the gall-bladder: or elſe ſhe has placed other muſcular machines round them, which, by acting at convenient times, expel their continued fluids; as, for example, in the muſcular coat of the ſtomach and inteſtines.

In other parts ſhe has added contiguous and incumbent muſcles to promote the diſcharge, as in the biventers and maſſeters of the lower jaw: or elſe ſhe has again joined to them a nervous irritability, which, being excited to action by any ſtimulus, opens the ſhut paſſages to the milk, ſeed, tears, &c.; or being touched by ſomething acrid, as already mentioned, diſtils the liquor more quickly; as happens to the bile, liquor of the ſtomach and inteſtines, and to the ſebaceous matter.

CHAP. IX.

Of RESPIRATION.

CCXXXIV. THE lungs completely fill the ſacks formed by the pleura; (LXXVII, LXXVIII.) We give this name to the two viſcera, which are diſtinguiſhed into right and left, having a broad baſis below, and terminated above at the firſt rib by an obtuſe point or cone. Anteriorly they are flat, externally convex, poſteriorly round, and in the middle concave to receive the heart. The right lung is larger than the left; and more frequently divided into three diſtinct lobes; the left lung more rarely. They are freely ſuſpended by the great blood-veſſels; unleſs you call that a ligament, which is made by the external membrane of the pleura, going to the lungs and to the baſis of the diaphragm. Betwixt the lungs and pleura is found a watery or rather ſerous vapour, of a coagulable nature, like that of the pericardium (LXXXII.); which vapour tranſudes from the ſurface of the lungs, continually in the fœtus, and not unfrequently in the adult. This is ſometimes increaſed, ſo as to form a dropſy, or thickens to a kind of ſebaceous matter; or laſtly, concreting into fibres, joins the lungs to the pleura [73].

CCXXXV. The external membrane of the lungs is ſimple, and thinner than the pleura, although continuous to it. It is ſpread all over them, from the adheſion of the great blood-veſſels of the heart; yet ſo as to be capable of retaining wind eaſily, without breaking, after being ſeparated from the lungs. The ſame membrane covers the interſtice or mediaſtinum of the lungs, like a bridge. It is joined to the lungs by a cellular texture.

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[73] Many examples occur in ſubjects who have died of inflammatory diſeaſes; as, after a pleuriſy, the whole lungs have been found covered with a purulent and almoſt ſebaceous membrane: the ſame

CCXXXVI. The ſtructure of the lungs is a heap of lobes ſeparated from each other by intermediate intervals, in which is extended a looſe cellular ſubſtance. Their firſt diviſion is into two, which are larger; and a middle one, which is leſs; yet cohering, then they are again ſudivided internally, through a long ſeries, into leſſer lobules down to the leaſt, till at laſt the ſmall lobules terminate in very ſmall membranous cells; which in adults, are variouſly figured, and full of air, and communicate on all ſides with one another. Theſe veſicles of the lungs, therefore, do not receive the air by a ſingle orifice from the wind-pipe, as a vial; but the air, exhaling from the leaſt branches of the ſaid wind-artery, is admitted in ſuch a manner into their irregular ſpaces, that it freely ſpreads through them from any one part of the lungs into all the reſt, and returns again in like manner. This is demonſtrated by inflation, which drives the air even through the leaſt branches of the wind-pipe into the ſmalleſt lobes; from whence it readily paſſes into all the reſt. Nor, in man and ſmaller animals, is the cellular fabric of the intervals ſhut up from the veſicles of the lungs, nor are the lobes ſurrounded by any peculiar membrane; for in the largeſt, as between the air-veſicles and thoſe cellular ſpaces ſurrounded with lobules, there is no commerce.

CCXXXVII.

ſame thing may be ſaid of the kidney in an hepatitis, and of the whole alimentary canal in caſes of enteritis. I remember two very ſingular caſes. In a child of four years, labouring under ſcrophulous complaints, winter 1778, a thick membrane, difficultly ſeparable, covered the lungs; and in the year 1769, I deſcribed a ſimilar covering between the pia and dura meninges.

CCXXXVII. The air is driven into theſe veſicles thro' the wind-pipe, which ariſes from the larynx (hereafter to be deſcribed), and from that only receives its air. The firſt part of this wind-pipe is ſingle, and deſcends along the ſmooth bodies of the vertebræ of the neck, partly fleſhy and partly cartilaginous; namely, within the cellular ſubſtance that ſurrounds the wind-pipe, is formed a canal made up by a ſucceſſion of cartilaginous and muſcular rings. Theſe are thin and elaſtic; flatter and thicker in their foremoſt part, but thinner in their poſterior extremities, which are conjoined by ſtrong tranſverſe muſcular fibres; which adhering firmly to each extremity of the cartilage, complete the circle. The lowermoſt circles are leſs; the uppermoſt often augmented by an appendix; the next again perpendicular to the diviſion.

CCXXXVIII. The fleſhy rings, alternately placed with the cartilaginous ones, are made up of red muſcular fibres. Some of theſe are tranſverſe, connecting the detached ends of the annular cartilages; others deſcend from each upper to the next lower ring. But other muſcular fibres again, deſcending downwards from the cricoide cartilage, and having reached below the firſt diviſion of the bronchia, vaniſh within the lungs. The tranſverſe fibres contract or leſſen the diameter of the wind-pipe; the longitudinal ones render it ſhorter. Alſo within the lungs, betwixt the imperfect rings, is found a ſort of muſcular fabric, but leſs uniform.

CCXXXIX. In the cellular coat which ſurrounds the muſcular one, but eſpecially in the back part of it, along the poſterior interval that is betwixt the cartilages, are placed numberleſs ſimple glands, which open by very ſmall ducts, like pores into the cavity of the wind-pipe: by which pores they depoſite a watery and pellucid mucus into that cavity; which mucus, being without the leaſt acrimony, not coagulable into a hard ſubſtance like the humour of the eye, is of the greateſt uſe in defending theſe moſt ſenſible membranes from being injured by an impure air, full of particles, which, by their mechanical figure or chemical acrimony, might be very troubleſome. Laſtly, the internal tube of the wind-pipe is completed or lined by a membrane, which is continuous with that of the mouth, ſmooth, ſoft, and very irritable. The ſame cellular texture ſurrounds it which anſwers to the muſcular coat.

CCXL. The veſſels of all this part of the wind-pipe come in the neck from thoſe of the lower thyreoids; in the thorax, from other ſmall branches of the ſubclavian trunks, the mammaries, and the *bronchials* properly ſo called. Its nerves are numerous from the recurrent and intercoſtal ones.

CCXLI. In the upper part of the thorax, the wind-pipe is received between the laminæ of the poſterior part of the mediaſtinum; and at the third vertebra, or a little above, is divided into two branches reſembling the trunk itſelf, formed like imperfect cartilages, alſo furniſhed with ſimilar glandules; each of which branches enters the lung to which it correſponds, only the right is ſomething ſhorter and larger than the left. Having entered the lungs, the cartilaginous rings change into fragments, which become more and more difform, gnomonic, angular, triangular, and intermixed with a larger portion of the membrane, till at length, the cartilage decreaſing, the laſt branches of the bronchia become merely membranous.

CCXLII. Its laſt branches are inviſible, which exhale the air into the cellular ſpaces of adult lungs, and likewiſe receive the watery vapours exhaling from the arteries into the ſaid ſpaces; from whence they are thrown out by exſpiration.

CCXLIII. The blood-veſſels of the bronchia are the *arteriæ & venæ bronchiales*. The former are almoſt conſtantly two; one coming from the upper intercoſtal of the aorta, which is diſtributed either to the right only, or to both the lungs; the other, from the trunk of the aorta itſelf, going to the left lung. Sometimes there are more than two bronchial arteries to be ſeen; as, when there are three, by the addition of a ſecond from the aorta. But ſometimes again there is only one artery in common. The thoracic part of the bronchia ſituated without the lungs, has its proper veſſels from the aorta, the ſubclavian, mammary, or intercoſtal. The bronchial veins are moſt commonly two; the right from the vena azygos, the left from a peculiar branch of the ſubclavian vein and the left ſuperior intercoſtal. Theſe blood veſſels travel together with the branches of the wind-pipe; and deſcend into their membranes in ſuch a manner, that the pulmonary arteries, in their way, inoſculate with their contiguous arteries, as the veins likewiſe communicate with each other. There are ſome inſtances where the pulmonary vein itſelf has given ſmall branches to the lungs, to the wind-pipe, and to the ſurface of the lungs.

CCXLIV. But there are other larger veſſels belonging to the lungs, called the *pulmonary artery* (deſcribed CVI. CVIII.), and the pulmonary vein (CX.) The great artery, in the fœtus larger than the aorta, and in the adult but little leſs, has two branches; the right larger but ſhort, the left narrower and longer. In the fœtus, the trunk itſelf is continued into the deſcending aorta, and is known by the name of *ductus arterioſus*. In an adult, that trunk degenerates into a ſolid ligament. The four pulmonary veins accompany the arterial branches and the aſpera arteria of the windpipe in their courſe through the lungs, ſurrounded with a good deal of cellular ſubſtance; which ſubſtance, being increaſed, at laſt compoſes the lungs themſelves. Within this cellular fabric, and likewiſe upon the ultimate ſpaces or cells, the air-veſſels and blood-veſſels are ſubdivided, ſpread, and interwoven like a net; and here the ſmall arteries exhale a plentiful vapour into their cells, and the veins abſorb a watery vapour from the ſame cells. Hence water tinctured, the whey of milk, or a thin waxen injection, being urged into the pulmonary artery, flows with a froth into the windpipe; or, on the contrary, being urged from the windpipe into the lungs, they penetrate into the pulmonary artery. In like manner, injections paſs from the pulmonary vein to the windpipe; or from thence again they may be forced into the veins. Laſtly, a liquor injected by the arteries, readily enters the pulmonary veins; and the reverſe.

CCXLV. The lymphatic veſſels, as in other parts, form a net-work upon the ſurface of the lungs, from whence there are branches conveying the lymph to the cavity at the back part of the mediaſtinum, and to the ſmall glands which lie behind the œſophagus, opening at laſt into the thoracic duct. The anterior pulmonary [74] nerves are ſmall, but the poſterior ones

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[74] I do not comprehend in what poſſible ſenſe the lungs can be ſaid to have neither many nor conſiderable nerves: For if I conſider the number and magnitude of the bronchial nerves, I would be inclined to ſuppoſe, that the lungs, of all the human viſcera, the organs of ſenſe excepted, receive, upon compariſon, many nerves, and therefore poſſeſs ſenſibilty. From many obſervations, I have found, that the primary fountain of the pulmonary nerves is the eighth pair, which generates the leſs anterior pulmonary plexus, conſiſting for ordinary of three branches; and the greater poſterior pulmonary plexus, formed of three or four larger branches, and two, three, and even four, leſs filaments: ſeveral branches are added to theſe from the recurrent and cardiac nerves; and ſometimes ſome filaments on the right ſide from the phrenic nerve, which intermix with the anterior plexus. But we ſhall only deſcribe the elegant fabric of the anterior plexus, being leſs known, as we have obſerved it in the right ſide in ſeveral ſubjects. A remarkable branch deſcends from the eighth pair behind the egreſs of the recurrent forewards, between the arteria anonyma, or common trunk of the ſubclavian and right carotid. Here a few branches being given to the coats of the artery, it ſeparates into two; one of which makes the cardiac; the other reaches the bronchia, and with it deſcends to the lungs, and ſends ſome branches more outwardly, which runs on with another larger branch from the trunk of the eighth, and compoſes an elegant ganglion, which might

ones ſomewhat larger: they come from a nerve of the eighth pair; and there are alſo ſome ſmall nerves to the lungs from the recurrent, and likewiſe from the cardiac plexus, which enter together with the large blood-veſſels. Hence the lungs have but little ſenſation; that of the little nerves, however, divided after the manner of the bronchia, is very acute. Nor are the lungs of an irritable nature.

CCXLVI. The quantity of blood which enters into the lungs is exceedingly great, equal to (or even perhaps greater than) that which is ſent in the ſame time throughout the reſt of the body; which, therefore, demonſtrates ſome very conſiderable uſe proper to this viſcus. And that this uſe depends manifeſtly upon the air, appears from the univerſal conſent of nature, in which we ſcarce find any animal without breathing; alſo from the ſtructure of the lungs in the fœtus, in which, for want of air, they are uſeleſs, receiving only a ſmall portion of the blood, which the pulmonary artery conducts from the heart. We come next, therefore, to ſpeak of reſpiration, by which the air is drawn into and expelled from the lungs.

CCXLVII. The element of air appears, from the principles of philoſophy, to be an elaſtic and ſonorous fluid, with a ſpring which cannot be deſtroyed. But the atmoſpherical air, which we commonly receive into the lungs, is impure, filled with a great quantity of watery and other vapours, alſo with ſalts and the univerſal acid, with the ſeeds of plants and animals, and other foreign matters; but in very minute particles, having a ſpecific gravity 859 times leſs than water, a cubic foot of air weighing between 610 and 694 grains. This air, which ſurrounds the earth on all ſides, being preſſed by the incumbent columns of its own maſs, perpendicularly, laterally, and in all directions,

might be called *pulmonary*, ſituated behind the vena azygos, at its entrance into the cava. From this ganglion come out five or ſix branches, with blood-veſſels and branches of the bronchia, and are diſtributed through the lungs.

rections, enters wherever it meets a leſs reſiſtance, and with a conſiderable force, as appears from experiments made with empty or exhauſted veſſels, and by the air-pump; ſo that its preſſure on the human body is not leſs than 3000 pounds weight. It is repelled chiefly by the pores of the membranes, which yet are permeable by water: it likewiſe penetrates oil or mucus with difficulty.

CCXLVIII. This air is excluded from all parts of the human body by the ſurrounding cloſe ſkin, which, even when dried or tanned, is impervious to the air; but more ſo, as under the ſkin is placed the fat, making an equal reſiſtance to the narrow openings of the abſorbing veſſels. It, therefore, now remains for us to inquire, why the air enters the lungs of an adult perſon; for with this they are in a manner conſtantly full, and of courſe are equally preſſed, and reſiſting againſt the weight of the whole atmoſphere: but that the lungs always contain air, is evident; becauſe, however cloſe you compreſs them, they will be ſtill lighter than water; and even in the fœtus, after they have been inflated but a few times, they always ſwim; whereas they ſink to the bottom of water, if they have not given admittance to the air.

CCXLIX. The equilibrium of the air's preſſure being removed in any place, it conſtantly deſcends or flows that way where it is leaſt reſiſted (CCXLVII.) But air that is denſe and heavy will deſcend more eaſily than ſuch as is light, whoſe force ſcarce overcomes that of the air which is already in the lungs, nor is able by the ſame force to overcome the reſiſtance of the bronchia, and force by which the lungs compreſs the air contained in them. Hence an animal lives better in a denſe than in a light air: altho' that kind of air is always moſt tolerable, which is pure at the ſame time that it is light; ſuch as that of the higheſt mountains of the Alps. Therefore, for the air to enter the lungs, they muſt make a leſs reſiſtance to it than before; namely, the air, which is already in the cellular fabric of the lungs, muſt be rariſied:

rified: but this effect will follow, if the cavity of the thorax, in which the lungs are contained, and which they exactly fill, be dilated. Thus the air, which is always in the lungs, expands into a larger ſpace; by which, being weakened in its ſpring, it makes a leſs reſiſtance to the external air; and conſequently a portion of the ſaid external air deſcends into the lungs, ſufficient to reſtore the confined and rarefied air, filling the lungs to the ſame denſity with that of the external air,

CCL. We muſt therefore deſcribe the powers which dilate the thorax to produce this effect. The breaſt or *thorax* is a ſort of cage made up of bones, muſcles, and cartilages; being almoſt of the ſhape of an oval tub, ſomewhat compreſſed before, but behind divided by an eminence, whoſe hoops are the ribs, which are of a remarkable ſtrength. In the lateral parts of this cage are placed the lungs; in the middle and lower part lie the pericardium and heart; after which it is taken up by ſome of the abdominal viſcera.

CCLI. The baſis of the thorax is formed by a column, a little crooked and gibbous on the upper and back part; and likewiſe, in that part of the baſis which is uppermoſt, the ſame is very much behind the others, into which twelve vertebræ coaleſce. They coaleſce, however, by the union of their bodies into a ſingle column, which is prominent in the forepart between the two cavities of the breaſt; divides the right from the left; and is plane in the forepart, and broad towards the ſides. A ſlight ſinuoſity receives the ribs in that place where the arch ſeparates from the body. They are bound together into one column, as well by the elaſtic plate interpoſed between every two bodies and coaleſcing with both, as by other ligaments and ſpines lying upon one another, and the joining of the ribs, by which means no motion can happen among them without the greateſt difficulty. The ſides of the breaſt are made up of twelve ribs. Theſe are in general bent in the form of an irregular arch, having a great curvature laterally and backwards, but extending in their forepart towards a right line. The bony parts of the ribs lie ſufficiently parallel with each other; the greateſt part of the rib is bony, round, and thick backward, but thin and flat forward. The other part forward is completed by a cartilage; which in general continues the figure of the rib, growing in a flat broad concavity of a nature different from the bony part, and which does not change into bone, unleſs in extreme old age.

CCLII. The poſterior and bony thick part of each rib terminates in a head; along from which, in the body of the uppermoſt and two lowermoſt ribs, runs a cavity or groove, formed in the other ribs, betwixt every two adjacent margins, which lie one towards the other. The vertebræ are tied to the ribs by ſtrong ligaments, of which the principal ſpread from each rib like rays into the next adjacent vertebra, other ligaments tie the tranſverſe proceſs to the tubercle of the rib, and others tie the ribs one to another and to the tranſverſe proceſſes at the ſame time. Moreover, betwixt the angle of incurvation and the juncture with the vertebra, each of the ten upper ribs ſend out a protuberance, which being articulated with the plain ſide of the tranſverſe proceſs of each vertebra, are ſo tied by ſhort and ſtrong ligaments to that proceſs, that the rib has liberty to make a ſmall aſcending and deſcending motion, but with a conſiderable degree of firmneſs.

CCLIII. Among theſe anterior cartilages, the ſeven uppermoſt reach to the ſternum, and enter into the lateral cavities which are incruſted with a cartilage in that bone, to which they are alſo made faſt by ſhort ligaments. Of the five remaining ribs, the uppermoſt is faſtened to the ſeventh preceding, and that to the next lower, by a ſtrong cellular texture, by which they form a continuous margin, which is at laſt alſo faſtened to the ſternum. The ſame are connected to one another both by proper ligaments, and cartilaginous appendices joined with them through the cellulosity: the two lowermoſt are free, and connected only with the muſcles. Theſe inferior cartilages are united to one another and to the ſternum by ſtrong ligaments.

CCLIV. The firſt rib is the ſhorteſt, but more ſolid than any of the reſt. As they follow in ſucceſſion to the ſeventh and eighth, every two and two ſtretch themſelves into longer and more moveable circles. The eighth is the longeſt of all; and from thence, the lower down they are, they grow continually ſhorter.

CCLV. The direction of the upper rib is deſcending; but the ſecond rib joins the ſternum almoſt in a right angle, while the others aſcend both to the vertebræ and to the ſternum, but more to the latter. But the bony part of the ribs is placed in ſuch a direction, that the uppermoſt have their ſides in the forepart very much declined forward, almoſt tranſverſely. In the third ribs it is placed almoſt perpendicularly; in the middle ones, it projects a little outward in the lower part. Beſides, the ſtrength of the different ribs is very different. The uppermoſt, being ſhort, rather grow into the ſternum than form a joint with it; and being tranſverſe, and often as it were welded together, they make a very ſtrong reſiſtance. From thence the mobility increaſes downwards, till the loweſt rib, adhering only to muſcles, has the moſt eaſy motion.

CCLVI. The ſternum in general is a thin ſpungy bone, altogether one in adults, but is variouſly divided in the fœtus. Its upper and broader part reſembles an octagon; and is articulated with the clavicles, which are jointed very cloſely with the triangular head of the ſternum, and with the firſt rib on each ſide. The other part which is longer and narrower, grows broad downwards, and its ſides receive the ribs each into its proper angular cavities. The lower part, which is leſſer and ſhorter, imitates the obtuſe figure of a tongue. This is continued into a detached appendix, partly bony and partly cartilaginous, of a changeable figure, which they call the *enſiform* cartilage; and which is found of various ſhapes, ſometimes being obtuſe like a little tongue, ſometimes pointed like a ſword, ſometimes cleft, and ſometimes perforated.

CCLVII. In order, therefore, to dilate the ſeat of the lungs, and thus to put the body in ſuch a ſtate that the external air may ruſh into the lungs, it is neceſſary for the thorax to be elevated. By this means all the ſections of the thorax form right angles, and its capacity is increaſed. This motion is performed by various muſcles, which either operate conſtantly or only at certain times. The intercoſtal muſcles, therefore, all of them act perpetually in elevating the ribs. By this name we underſtand 22 muſcles; of which 11 are external, or next the ſkin; and as many internal, ſeparated from the pleura only by fat or cellular ſubſtance. The begining of the *outer intercoſtals* is at the poſterior articulation of the ribs (CCLII.); but the termination of them is in the anterior bony part of each rib, at ſome diſtance from the cartilage, in ſuch a manner, that the remaining ſpace betwixt the cartilage and ſternum to the muſcle is filled by a tendinous expanſion. The direction of theſe muſcles is ſuch, that the fibres deſcend obliquely forward, from the lower edge of the upper rib to the upper edge of the lower rib. And that their action is to elevate the ribs, all authors unanimouſly agree; becauſe they thus deſcend from the upper leſs moveable to the lower and more eaſily moveable rib, in ſuch a manner, that their lower point lies more diſtant or remote from the hypomochlion, or point of motion, which is in the coſtal articulation with the vertebræ, conſidering the rib as a lever.

CCLVIII. But the *internal intercoſtals* ariſe at ſome diſtance from the vertebræ, almoſt at the outer tubercles of the ribs beforementioned (CCLII.) From thence they proceed as far as the ſternum, into which the uppermoſt of theſe muſcles are inſerted above. The direction of theſe is contrary to that of the former, except the anterior part of the firſt or uppermoſt of them; ſo that they deſcend from the lower margin of the upper rib backward, to the upper edge of the lower rib forwards. Therefore ſome doubt of their action, becauſe their lower part is inſerted into that portion of the rib which is neareſt its articulation with the vertebræ, and which therefore ſeems to be the leaſt moveable: however, they elevate the ribs notwithſtanding this; for the great firmneſs or immobility of the upper rib, exceeding that of the lower, is evident from the articulation, weight, and ligaments there formed, which ſurpaſſes that mobility, ariſing from the greater diſtance of the centre of motion. This appears from the diſſection of living animals; in which we ſee the inner intercoſtal muſcles operate in the elevation of the ribs, and reſt in the depreſſion of them alſo from a flexible thread fixed to the rib of ſome human ſkeleton, and drawn in the ſame direction with that of the fibres of the inner intercoſtal muſcles; by which means the lower rib will be always approximated towards the upper. The greater firmneſs alſo of the upper ribs proves this, as they ſerve for a fixed point to the lower ones: for the firſt or uppermoſt ribs are from eight to twelve times firmer and leſs moveable than the lower true ribs; but the difference of diſtance in them from the centre of motion, is ſcarcely the twentieth part of the length of their whole lever. Laſtly, the elevating power of the internal intercoſtal muſcles appears plainly by experiment in a dead ſubject; when, by the thorax being raiſed, the muſcles inſtantly ſwell.

CCLIX. By the action, therefore, of theſe muſcles, the thorax is elevated, not altogether as one machine, nor would reſpiration be aſſiſted by ſuch a motion; but the ribs turning upon their articulations, though behind they are but little moved, yet the fore-part of their extremities deſcends, and forms larger angles both with the ſternum and vertebræ; but from thence in the middle of their arches, by aſcending, their lower edges are drawn upward. At the ſame time, the ſternum is thruſt out forward more from the vertebræ and from the ribs. Thus the ribs are both removed farther from the vertebræ, and the right ribs depart from the left; and the diameter on both ſides, betwixt the right and left ribs, betwixt the ſternum and the vertebræ, is increaſed almoſt to two lines: and therefore this enlargement, following in every imaginable ſection of the thorax, will ſufficiently dilate the cavity of the breaſt. This action of the ribs is more particularly complete in women, and in men who have no ſhortneſs of breath. Theſe effects are produced leaſt of all by the firſt ribs, but more by the following ones. In very ſtrong inſpiration, the ribs deſcend both behind and before; and, along with theſe, the ſternum and the ſpaces between the cartilage are leſſened. But this dilatation alone is not ſufficient for healthy breathing: nor is it ſo conſpicuous or evident in men; although, in them, the intercoſtal muſcles, by retaining and elevating the ribs, very much aſſiſt the inſpiration in a tacit manner, while they afford a fixed point to the diaphragm, that the whole force of that muſcle may be ſpent, not ſo much in depreſſing the ribs, as in urging down the abdomen. The greater part, therefore, of the ſpace which the thorax gains in inſpiration, ariſes from the action of the diaphragm.

CCLX. By *the diaphragm* we underſtand a muſcle expanded in a curvilineal plate; by which, in general, the pulmonary bags are ſeparated from the abdomen in ſuch a manner, that the middle and tendinous part of the ſeptum is nearly the higheſt, and ſupports the pericardium: its lateral parts, which ariſe from the ſolid parts of the thorax and loins, are every where lower; but the loweſt of all are thoſe which lie moſt backward. The fleſhy portions of this muſcle ariſe before from the inner or poſterior face of the enſiform cartilage, and from the ſeventh, eighth, ninth, tenth, eleventh, and apex of the twelfth, rib; after which follows an interval, in which the naked pleura lies contiguous to the peritonæum. From thence the muſcular appendices of the diaphragm, which are much the ſtrongeſt part of it, being collected on each ſide into two, three, or four round muſcular portions, ariſe fleſhy from the tranſverſe proceſs on each ſide of the firſt vertebra of the loins, and from the ſide of the body of the ſecond; tendinous from the middle of the body of the ſecond, third, and fourth, and with cartilages placed between them, always higher up in the left ſide, but lower down in the right[75].

CCLXI. All theſe fibres (CCLX.), becoming tendinous, form the centre of the diaphragm, which reſembles, in figure, an obtuſe index of a ſun-dial, having the middle of the larger angle ſupporting the pericardium, while the lateral angles or wings deſcend backward, the left being narrower than the right. This centre of the diaphragm is more moveable and at liberty than the reſt; except in the middle of its tendinous part near the fleſhy margin, where the incumbent heart makes a reſiſtance; but the lateral parts and the fleſhy portions belonging to them are the moſt moveable. The fibres of this tendon form a moſt beautiful web, principally indeed on the upper part; which ſtretches from the fleſhy part of each muſcle to the fleſhy part of the oppoſite one: thence remarkable inferior faſciculi are ſent off tranſverſely to the right and left, and alſo backwards, which laſt portion is the uppermoſt.

CCLXII. There are two holes in the diaphragm; of which that on the right ſide of its tendinous part is ſomewhat ſquare, and circumſcribed by four ſtrong tendinous portions; the left, which is elliptical, lies betwixt the right and left fleſhy portions, which ariſe from the middle of the bodies of the vertebræ of the loins: under this opening they decuſſate and croſs each other once or twice, but above they end in the tendon. This left opening is therefore drawn cloſe together in the contraction of the diaphragm, while it is probable that the other opening remains immoveable. The tendons are but little changed in the motion of the muſcles.

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[75] We muſt not omit, in talking of the riſe of the diaphragm, two tendinous arches on each ſide, made over the pſoas and quadratus, from which ſome ſlender muſcular fibres come out, and are interſperſed among the muſcles of the ſeptum tranſverſum, produced from the reſt of the ribs and part of the lumbar vertebræ.

CCLXIII. The ſtructure of the parts, and the diſſection of living animals, demonſtrate, that the fleſhy portions of the diaphragm, which on all ſides aſcend from the firm parts to the middle and more moveable, do, by their contraction, depreſs the ſame, and by that means draw downward the lateral bags of the thorax, which contain the lungs (LXXVII.); and, by this means, the perpendicular diameter of the thorax is conſiderably increaſed. The fleſhy parts are more depreſſed; the tendon leſs, both becauſe it is fixed to the pericardium, and becauſe its own ſubſtance does not contract. Even the œſophagus and vena cava are contracted, while the diaphragm exerts its action. So that the diaphragm almoſt alone performs the office of reſpiration in a healthy man who is at reſt; as alſo in that thorax whoſe ribs are fractured, or the ſternum burſt, or where the perſon will not make uſe of his ribs by reaſon of pain. The force of the diaphragm alſo, in dilating the breaſt, is greater, according to the calculations that have been made, than all the reſt of the powers which contribute to reſpiration. A ſtrong inſpiration is as yet confined; becauſe, during the greateſt exertion of the diaphragm, the lowermoſt ribs are brought inwards, and thus far the thorax is ſtraitened. Leſt this ſhould always happen, the intercoſtal muſcles interfere in ordinary inſpirations; in very great ones they are inferior to the diaphragm. The phrenic nerve, which is more eaſily irritated than in moſt other muſcles, forces the diaphragm to perform its office. The lungs themſelves are altogether paſſive or obedient to the action of the air, ribs, and diaphragm; to which they are preſſed into cloſe contact on all ſides, as through a large wound; and when the thorax is denudated by the knife, leaving its capacity entire, the lungs appear through the pellucid pleura and diaphragm.

CCLXIV. But in larger inſpirations, which receive a greater quantity of blood driven into the lungs, and when there is any obſtacle or difficulty oppoſed to the action of the lungs themſelves; in thoſe caſes, ſeveral other powers conſpire to elevate the thorax: which powers are inſerted either into the thorax, clavicles, or ſcapulæ; ſuch as the ſcaleni muſcles, trapezii, cervicales deſcendentes, ſerrati ſuperiores, and pectorales; together with the ſmall elevators; of which a more ample deſcription may be had from profeſſed ſyſtems of anatomy.

CCLXV. We have now ſurveyed the powers which are able to increaſe the capacity of the thorax in all its three dimenſions (CCLXIII. and CCLIX.) By theſe the cavity of the breaſt is dilated, ſo that it compreſſes the lungs leſs than before: the lungs then ſtrive to diffuſe themſelves over that ſpace, ſeeing they are never deſtitute of air, which expands itſelf by its elaſticity as ſoon as the preſſure is taken off. Without that muſcular force the lungs have no proper power of their own by which they are capable of attracting air: and even when they are moſt full of air, by having the aſpera arteria cloſed, the animal vehemently attempts to inſpire, by the efforts of its intercoſtal muſcles and diaphragm. It therefore remains, that the air (CCXLVII.), which is a heavy fluid, and preſſed on all ſides by the incumbent columns of the atmoſphere, muſt now enter the thorax with the greater force the leſs air the lungs contain; or yet more powerfully, if they contain no air: but with no force at all, if the air admitted through a wound in the breaſt preſſes upon the ſurface of the lungs. In this action, therefore, which is called inſpiration, the bronchia are every way increaſed, both in length and diameter; becauſe all the diameters of the thorax are increaſed: but in this act, the inflated lungs always follow cloſely contiguous to the pleura without leaving any intermediate ſpace. At the ſame time, the pulmonary blood-veſſels, which are wrapped up, together with the bronchia, in a covering of the cellular ſubſtance, are likewiſe with them extended in length, and ſpread out from ſmaller into larger angles; by which means, the circulation through them is rendered eaſier. While this is performing, the veſicular ſubſtance, or fleſh of the lungs themſelves, filled with air, increaſes thoſe ſpaces through which the capillary blood-veſſels of the lungs advance; whereby the veſicular preſſure, upon each other, and upon thoſe veſſels adjacent, is leſſened: thus, therefore, the blood will flow with greater eaſe and celerity into and through the larger and ſmaller veſſels of the lungs. Hence a dying animal is revived by inflating its lungs, and facilitating the paſſage of the blood to the left ventricle of the heart; and thus people, ſeemingly dead by being kept a long time under water, are again recovered. But as for the preſſure of the air upon the blood in the lungs in this action, it is ſo inconſiderable as not to deſerve our notice, as being 300 times leſs than the force of the heart; nor can it ever urge the air into the blood, as it may be eaſily forced by art with a ſyringe.

CCLXVI. It is by ſome queſtioned, Whether there be not air betwixt the lungs and the thorax? and whether this air, being rarefied in inſpiration, is not afterwards condenſed, ſo as to compreſs the lungs, and cauſe exſpiration? And they again aſk, Whether this opinion be not confirmed by the inſtances of birds, in which we find this matter to be truly ſo[76]?

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[76] By Camper's very elegant diſcovery, it is certain, that air paſſes into almoſt all the long bones of birds flying much in the higher

But we ſee every thing concurs to confute this opinion: for, immediately behind the pleura, in living quadrupeds, as well as in dead human bodies, the lungs are viſible, without any intermediate ſpace bewixt them; but the pleura being perforated, the lungs are immediately, by the contiguous air that enters, preſſed together towards the vertebræ. In birds, indeed, the lungs, being pervious to the air, admit it into the cavity of the thorax through large holes in their ſubſtance. But in theſe there is a manifeſt ſpace betwixt the lungs and the pleura. Large wounds, admitting the air only into one cavity of the thorax, diminiſh the reſpiration; but ſuch wounds as let the air into both cavities, quite ſuffocate or ſuppreſs the reſpiration. The thorax being opened under water, ſends out no bubbles of air through the ſaid water[77]; but in birds it does, becauſe they have air in their thorax. The imaginable ſpace betwixt the lungs and the thorax is always filled up by a watery or ſerous vapour, or elſe by the ſame vapour condenſed into a watery lymph. If the lungs adhere, they injure the reſpiration but in a ſmall degree; which ought entirely to ceaſe, if it required an intermediate air betwixt the lungs and thorax

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higher regions, into the cavity of the ſternum, the vertebræ, cranium, inferior maxilla, both from the lungs and through the Euſtachian tube, and goes from one cavity into another: ſo it does not ſeem improbable, that the ſame may paſs out by the ſurface of the body. But in birds, who ſoar not ſo high, the air gains admiſſion through fewer bones. It is a pretty and ſufficiently agreeable experiment, to perforate the humerus or femur; and the air inflated into the aſpera arteria comes out at that foramen with the blood, which it has changed into froth; and *vice verſa*, the air inflated through the hole diſtends the lungs. In like manner, I have ſeen mercury injected into a foramen of this kind make its appearance in the lungs.

[77] Though it is my deſign, neither to renew this diſpute, nor to ſtart one of my own, it will not be, however, ſuperfluous to mention an experiment which I have often repeated on dead born infants: as oft as I have opened under water the thorax of ſuch children, not affected with any mark of putridity, I never obſerved any bubbles of air appear.

thorax. Finally, the external being admitted to any of the internal membranes of the human body, deſtroys their texture, if they are not defended by a plentiful mucus; of which we can find none upon the ſurface of the pleura.

CCLXVII. But reſpiration, whether by the admixture of a ſubputrid vapour, or by ſome other method, certainly vitiates the air, and renders it unfit either for inflating the lungs or ſupporting flame; and laſtly, it deprives that element of its elaſticity. We may ſuppoſe that this happens from putrefaction, ſeeing the air is rendered peſtilential by a crowd, and fevers of the moſt malignant kind are thus generated in a few hours. But in whatever manner this is produced, we are certain that the air is vitiated in the lungs; loſes its elaſticity; and thus cannot keep the lungs diſtended, ſo as to tranſmit an increaſed quantity of blood through the dilated pulmonary arteries into the veins. Nor can the will dilate the breaſt beyond certain bounds, or aſſiſt that paſſage of the blood in an unlimited manner. A ſtate of body therefore will take place, in which the blood cannot paſs through the lungs.

CCLXVIII. Thus is generated a new reſiſtance to the blood continually coming from the heart: and in long retentions of the breath, as in making violent efforts, the venous blood, eſpecially of the head, ſtagnates before the right ventricle of the heart being ſhut, becauſe it cannot evacuate itſelf into the lungs; and thus ſwells up the face with redneſs, ſometimes burſts the veins of the brain, neck, inteſtines, kidneys, and laſtly of the lungs, and right auricle of the heart. This occaſions prodigious anxiety and uneaſineſs to the ſpirits; this alſo is the cauſe of death in compreſſed air, in drowned people, and ſuch as are ſtrangled, which is much more ſudden than is commonly imagined. A living perſon therefore, that he may remove thoſe inconveniences which flow from an obſtruction of the paſſage of the blood, ſlackens the powers of inſpiration, and excites thoſe of exſpiration, which free the breaſt from an air too greatly rareſied.

CCLXIX. Theſe powers are, firſt, the elaſticity of the ribs, which being drawn upwards out of their natural ſituation, as ſoon as the powers which elevated them ceaſe to act, ſpontaneouſly place themſelves, ſo as to make more acute angles with the ſternum and vertebræ. To this end conduces likewiſe the elaſtic force of the bronchia and veſicles diſtended with air, which ſtrive to contract themſelves. Hence exſpiration is performed more eaſily and quickly than inſpiration; and hence it is the laſt action of dying people.

CCLXX. To this alſo contribute the oblique muſcles of the abdomen, together with the ſtraight and tranſverſe ones. The former of theſe are, in one part of them, faſtened to the lower ribs; and, in another part, they are attached to the os pubis and ilium, as a fixed point with reſpect to the breaſt. Therefore the ſtraight muſcles, being contracted, depreſs the arch or convexity, into which the abdominal viſcera are thruſt by the diaphragm, and bring the ſame nearer to a ſtraight line: at the ſame time the abdominal viſcera are preſſed by thoſe muſcles upward and backward againſt the diaphragm, which alone is able to give way; and yield up into the thorax, which at that time is rendered ſhorter. The oblique muſcles, for the ſame reaſons, compreſs the lateral parts of the abdomen, and urge the liver and ſtomach backwards, and preſs them towards that place where there is the leaſt reſiſtance. Laſtly, they draw down the ribs which were before elevated by the intercoſtals. The tranſverſe muſcles, indeed, do not draw the ribs; but they pull the cartilages of the falſe ribs a little inward, and render the whole capacity of the abdomen leſs, while at the ſame time they preſs the viſcera againſt the diaphragm. Along with theſe we may reckon the powers of the ſternocoſtal and long intercoſtal muſcles which are called *depreſſors*. By this joint force the ſuperior ribs deſcend; but the middle ones more, the uppermoſt leſs, the loweſt moſt of all; and the ſame are brought inwards by their margin: the cartilages aſcend, and return into acute angles with the ſternum; and the ſternum itſelf returns backwards with the ribs. By theſe means the thorax, contrary to its former ſtate (CCLIX.), is every where rendered narrower and ſhorter, ſo as to expel as much air out of the lungs as is ſufficient to relieve the uneaſineſs cauſed by its retention (CCLXVIII.)

CCLXXI. In more powerful reſpirations, when the inſpirations are made greater, the exſpirations are likewiſe increaſed by the aſſiſtance of ſome other powers, as of the ſacrolumbalis, longiſſimus and quadratus muſcles of the back and loins. This force, by which the air is blown out of the lungs, is ſufficient to carry a leaden bullet, weighing above a dram, to the diſtance of 363 feet; which force is equal to a third part of the preſſure of the atmoſphere. But, in a healthy perſon, the muſcles of the abdomen alone ſuffice to an eaſy exſpiration, in which the lungs are not ſo much emptied of air as they are by a violent efflation.

CCLXXII. The effects of exſpiration are, a compreſſure of the blood-veſſels in the lungs, a reduction of the bronchia into more acute angles, a preſſure of the reticular ſmall veſſels by the weight and contact of the adjacent larger veſſels, and an expulſion of the corrupted blood from the lungs; by which means part of the blood heſitating in the capillary arteres, is urged forward through the veins to the left ſide of the heart, while at the ſame time that part of the blood is reſiſted, which flows in by the artery from the right ventricle. Exſpiration, therefore, will ſtop the eaſy paſſage of the blood through the lungs; and when the whole thorax is compreſſed together, repels the venous blood into the veins of the head, and fills the brain and its ſinuſes.

CCLXXIII. In this manner a freſh neceſſity follows for repeating the reſpiration; becauſe the collapſed veſſels of the lungs reſiſt the blood repeatedly expelled from the right ventricle of the heart. And this makes another cauſe of death in thoſe animals which expire in veſſels exhauſted of air: for, in ſuch, the lungs having the air drawn out from them, appear denſe, ſolid, and heavier than water; whence they are rendered impervious to the blood. Of the ſame kind is the death of thoſe who are killed by lightning, and perhaps by the noxious vapours of caverns. Thus, therefore, by the power of a moſt wiſe fabricature, the organs of exſpiration are relaxed ſo ſoon as that uneaſineſs is perceived, which ariſes from the hindrance of the blood's courſe through the lungs; and hence the powers of inſpiration are excited into action, whereby the motion of the blood through the lungs is rendered free and quicker.

CCXXIV. It is by ſome queſtioned, whether or no there are not other cauſes of alternate reſpiration? whether or no we may hope for any diſcovery in this matter, by compreſſing the vena ſine pari, the phrenic nerve, or intercepting the blood ſent to the brain? But thoſe are repugnant to comparative anatomy; by which we always find the ſame alternation in the breathing of the animal, independent of any ſuch nerve or vein. Whether or no reſpiration is from the alternate contraction of the antagoniſt muſcles, among which thoſe of exſpiration relax the others of inſpiration, and the reverſe? But in this manner, all the muſcles of the human body are perpetually in an alternate motion.

CCLXXV. From what has been hitherto ſaid, it appears, that reſpiration is unavoidably and abſolutely neceſſary to life in a healthy adult perſon; becauſe, whether the lungs remain long in a ſtate either of exſpiration or inſpiration (CCLXXIII. CCLXXVIII.), we ſee death will be the conſequence. Therefore no animal that has lungs like ourſelves, after it has once breathed and received the air into the inmoſt parts of the lungs, and by that means brought a new and large quantity of blood to that viſcus, can ſubſiſt longer

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than a few minutes without the uſe and benefit of a free air; but it will either periſh, or at leaſt fall into ſuch a ſtate as differs from death only in its being recoverable again by certain powers or actions. In an animal lately born, this neceſſity for air does not take place ſo ſuddenly.

CCLXXVI. But the uſe of reſpiration is different from this neceſſity; which nature might have avoided, either by uſing no lungs at all, or elſe by diſpoſing them in a manner reſembling thoſe of the fœtus. This uſe, therefore, of reſpiration muſt be very conſiderable, ſince all animals are either made with lungs, or with gills as in fiſh, or elſe with a windpipe diſperſed through all parts of the body.

CCLXXVII. In order to diſcover this uſefulneſs of reſpiration, let us compare the blood of an adult perſon to that of a fœtus, and alſo with the ſame vital fluid in fiſh. It appears then in a fœtus, that the blood is deſtitute of its florid redneſs and ſolid denſity; and in the blood of fiſh, we obſerve there is no heat, the denſity inconſiderable, and but little craſſamentum contained in it; and, therefore, all theſe properties, we are, by the nature of things, perſuaded, the blood acquires in the lungs.

CCLXXVIII. It may be aſked therefore, Whether the blood does not acquire its heat principally in the lungs? But this does not ariſe from the alternate extenſion and contraction, relaxation and compreſſion, of the pulmonary veſſels (CCLXV. and CCLXXII.), by which the ſolid parts of the blood are perpetually rubbed and cloſely compreſſed? The lungs therefore will add to the office of the reſt of the arteries, becauſe in them the blood is alternately relaxed and compreſſed more than in any other part of the body. But even when the lungs are obſtructed, ulcerated, and almoſt deſtroyed, a morbid heat ſeizes upon the body: but in the lungs the cold air very nearly touches the blood.

CCLXXIX. The denſity of the blood is, indeed, again promoted in the lungs, partly by the copious diſcharge of the watery vapour which is there ſeparated, by which the reſt of the maſs becomes ſpecifically heavier. But the ſame effect ſeems to follow here, as in other arteries, namely, from the attrition and preſſure which the blood here ſuffers in being alternately retarded, accelerated, and figured in its courſe through the modulating tubes of the leaſt veſſels, which give a ſphericity and denſity to the particles; hence it becomes denſer, as having more of the weighty globules, and leſs of the lighter fluid. And, in this reſpect, the pulmonary vein, being ſmaller than its correſponding artery, is of no ſmall uſe towards increaſing the attraction of coheſion betwixt the parts of the globules, ſo as to compreſs and bring them cloſer to each other. Nevertheleſs, cold animals, which have very ſmall lungs, have denſe and coagulable blood; as alſo a chicken before it is hatched. The blood alſo has a ſhort paſſage through the lungs: the paſſage through the whole body is longer, and the artery weaker; the heart, by which the blood is driven forward, is alſo weaker.

CCLXXX. It is therefore queried by ſome, Whether the air itſelf is not received by the blood in the lungs, ſo as to excite neceſſary vibrations therein? Whether this does not appear from the reſiſtance of bodies to the heavy external air; and from the air found in the blood-veſſels, in the cellular ſubſtance, and in certain cavities of the human body; alſo from the cracking obſerved by an extenſion of the joints; to which add, the air manifeſtly extravaſated from the windpipes into the hearts of certain animals, as in the locuſt; from air coming out of the blood and humours of animals in Mr Boyle's vacuum; together with a neceſſity of a vital oſcillation in the blood itſelf; and, laſtly, the increaſed redneſs of the pulmonary blood?

CCLXXXI. But that no elaſtic air is here received into the blood, is demonſtrated from the impoſſibility of forcing air into blood, if it retains its elaſticity; from the inutility of its reception, if the ſpring of it ſhould be loſt in the blood; from the perfect immutability of the blood, by cold; from the minuteneſs of the inhaling veſſels, with the mucus that perpetually lines the ſides of the veſicles in the lungs: to which add the nature of the elaſtic air itſelf, which is very unapt to paſs through capillary veſſels; with a repulſion of it by water, that hinders it from paſſing through paper, linen cloth, or ſkins that are wetted by water. Again, the air being driven into the windpipe, never paſſes to the heart; or whenever it does, it is forced thither by ſome great or unnatural violence: but the permanent air in the veſſels and humours of the human body, from a ſtate of inelaſticity, may become elaſtic by putrefaction, froſt, or an external vacuum. But ſuch permanent unelaſtic air is incorporated with all liquors; and taken into our bodies with the aliments and with abſorbed vapours, mixing ſlowly and with ſome difficulty. But there never were any elaſtic bubbles of air-obſerved in the blood of a living animal; and ſuch air being inflated into the blood-veſſels of any living animal, kills it certainly and ſpeedily. Nor is there any great certainty of the blood in the pulmonary veins being of a brighter red colour. Laſtly, though air indeed is abſorbed by moſt of our humours, yet that abſorption is performed ſlowly, and takes up the ſpace of ſeveral days after the former air has been exhauſted by the pump. It then likewiſe lays aſide its elaſtic nature; nor is there any reaſon produced, why the air ſhould either be more ſpeedily abſorbed by the blood, or why it ſhould retain its elaſticity after it is ſo abſorbed[78].

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[78] In theſe our times, it is now too much a matter of diſpute, as if it were a ſubject entirely new, I mean the different kinds of air; to wit, fixed, inflammable, narcotic, nitrous, &c. which were partly known to Helmont, Newton, Boyle, Camerarius, Hales, and ſeveral others; but the pneumatic theories in general have been remarkably elucidated, increaſed, and limited, as occaſion required, by the laudable induſtry of Drs Brownrigg, Black, Cavendiſh, Prieſtley, Spielman, Erxleben, &c. If, in a few words, I might offer my opinion about the air found in our bodies, which has been the baſis of ſo many diſputes, I am perſuaded, that

CCLXXXII. Whether or not is the blood cooled in the lungs; and whether or not does this ſeem to be true from the death of animals, in air which is hot to ſuch a degree as equals the heat of the hotteſt breezes in the moſt ſultry dog-days? Whether the pulmonary veins are not, therefore, leſs than the arteries; and whether the deſire of cold in people that are working hard does not ariſe from thence? That the blood is cooled in the lungs is thus far true, as it warms the contiguous air, and therefore loſes ſomething of its own heat. But that this was not the principal deſign of nature, is evident; ſince no one will ſay that the venous blood is hotter than the arterial, although ſome pronounce the former to be ſomewhat cooler; but nobody ever obſerved the left ventricle of the heart cooler than the right. But the venous blood enters the lungs; if it be there cold, it will follow, that the arteries muſt receive it in ſtill a colder ſtate. But then here the degrees of heat which the blood communicated to the air are again recovered by it. And, indeed, a perſon may live in an air much hotter than the blood itſelf; of which we have a familiar example in baths and the warm countries. The pulmonary artery in a fœtus, which does not reſpire, is greater; and the larger area of the right auricle and ventricle of the heart, is likewiſe

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that the atmoſpheric air is a very compound fluid, conſiſting of parts of a very different nature and quality; which parts, when mixed with any primigeneous fluid as a vehicle, make the common air we inhale in inſpiration. This primigeneous fluid is, perhaps, that air which we obſerve in animals, vegetables, and likewiſe in the earth itſelf, differing only according to the various ſubſtances with which it is united. If there is mixed in a due proportion with this univerſal fluid, any elaſtic, ethereal, electric principle, or any particles not yet fully underſtood, perhaps there will reſult ſalubrious atmoſpheric air. But it will become infected and noxious in various degrees, from an admixture of putrefactive ſubſtances, narcotic or inflammable ſuffocating elements. For that reaſon it ſeems to me very proper, that our judgment about the ſalutary or noxious quality of the air ſhould be directed by theſe principles; and hence it will be in our power to correct unwholeſome air, provided we know what qualities the air ſhould poſſeſs which is moſt properly ſuited to the function of reſpiration.

wiſe much greater in a fœtus; which ſeems neceſſary to reſerve and retard the blood, as the pulmonary vein being narrower accelerates it.

CCLXXXIII. Whether or not is the redneſs of the blood produced from the air? This is contradicted by what we ſee in cold animals, which, though they are almoſt entirely deprived of the uſe of air, have blood equally red with that of warm animals; from the certain connection of redneſs in the blood of frogs with their having plenty of food, and a paleneſs of it with a want of food; and from the air, as we have juſt now ſaid, being denied acceſs to the blood. Nevertheleſs, redneſs is produced when the air has acceſs to the blood, by which means it is alſo reſtored after it has been loſt; and, on the other hand, it is deſtroyed by the denial of the acceſs of air. Whether or not may not a more ſubtle element from the air penetrate the blood, and be the cauſe of its colour, as light is required for the colours of plants?

CCLXXXV. Whether the uſe of the lungs is to abſorb a nitre from the air + to the blood? or whether the florid colour, obſervable in the ſurface of a cake of blood, be owing to the ſame cauſe, while the bottom part looks of a dark and blackiſh colour? and whether or not this is a prſervative againſt the putrefaction of the animal? remain as queſtions with ſome. That there is a kind of volatile acid in the air is certain, ſince that meeting with a ſuitable earth forms nitre; for a nitrous earth, being exhauſted of its ſalt, and expoſed again to the air, becomes re-impregnated with more nitre. But the ſame univerſal acid, we know by certain experiments, meeting with a different ſort of earth, forms a vitriolic ſalt, or alum, or elſe ſea-ſalt. For the caput mortuum of ſea-ſalt, which remains after the diſtillation of the ſpirit, recovers ſo much ſtrength from the air, as enables it to yield more ſpirit by diſtillation; even in ſnow there is a cubical ſalt: but marcaſite perſpires a true vitriol; and colcothar recovers again the acid ſpirit, which was

+ Air contains no nitre —

was drawn from it; alſo fixed alkali, expoſed to the air, turns into a vitriolated tartar. This, therefore, cannot be the uſe of reſpiration, becauſe thoſe ſalts abound in too ſmall a quantity in the air for ſuch uſes; and air is fitteſt for breathing when pure in high mountains, where thoſe ſalts are the leaſt to be found; nor is there any nitrous ſalt as yet known to be found in our blood.

CCLXXXVI. If it be aſked, Why tortoiſes, frogs, lizards, ſnails, ear-wigs, and other inſects, live long without air? we anſwer, That in them the lungs are given not ſo much for the preparation of the blood, which they receive but in a very ſmall quantity, as for the uſe of ſwimming in the water: and from hence it is that their lungs are immediately joined with the vena cava and aorta. But inſects, we know, draw the air in, and exhale it again, through points in the ſkin. If it be aſked, Why all animals periſh in air that is confined or not renewed, although the animal be ſmall, ſuch as little birds? we anſwer, Becauſe the air, which has once entered the lungs, and been fouled by watery vapours, is rendered leſs elaſtic, and unfit for reſpiration, by alkaline vapours: not becauſe it becomes lighter; for the mercury falls but little in air which has not been renewed, and which has killed an animal. Hence it is that the animal ſurvives longer in air that is more compreſſed than that of the atmoſphere: for in that caſe there is a greater proportion of the elaſtic element, which takes up a longer time to corrupt. But, even in other caſes, confined air is rendered deſtructive only by ſtagnation, and filling it with vapours. But the reaſon why animals ſwell in an exhauſted veſſel, is, from the extrication and expanſion of the unelaſtic air lodged in the blood and other juices.

CCLXXXVII. There is a certain conſent or proportion between the pulſe and reſpiration; ſo that, according to the common courſe of nature, there are three or four pulſes counted to one reſpiration. But if more blood is ſent to the heart in a given time, the numbers both of the pulſe and reſpiration are increaſed. This is the reaſon of the panting or ſhort breathing in a perſon that exerciſes his body with any conſiderable motion; whereby the venous blood is returned faſter to the heart (CXLII.) But if the blood meets with a greater reſiſtance in the lungs, ſo that it cannot paſs freely from the right into the left ventricle of the heart; then reſpiration is increaſed, both in number and magnitude, in order to forward its courſe: and this is the cauſe of ſighing, yawning, and wheezing; of which the firſt is a deep inſpiration; the ſecond ſlow, and very great; and the third, a frequent and imperfect one. The number of reſpirations, however, does not always increaſe with the pulſe; of which we have an example in thoſe fevers where the lungs are not affected.

CCLXXXVIII. The mucus, which lines the ſenſible membranes of the air-veſſels in the lungs, may become troubleſome both by its quantity and acrimony; it has been known to cauſe even ſuffocation in a dropſy of the lungs. Therefore its quantity, adheſion, or acrimony, excites a cough; namely, an irritation of the reſpirative ſyſtem, by alternate large inſpirations, ſucceeded by large and quick exſpirations, together with ſudden ſhocks of the abdominal muſcles; by which the mucus, and ſometimes calculous matters, are expelled from the lungs.

CCLXXXIX. Laughter differs from coughing in its cauſe, which reſides commonly in the mind, or at leaſt conſiſts in a certain titillation of ſome of the cutaneous nerves; and, moreover, becauſe it is made up of imperfect quick exſpirations through the contracted glottis, leſt the air ſhould be totally evacuated from the lungs. Hence laughter, in a moderate degree, conduces to health; becauſe, in the time of one full inſpiration, many ſhort inſpirations and exſpirations happen, and thus the concuſſion is greater. Hence its danger of ſtagnating the blood;

becauſe the exſpiration is not full or entire, whereby the blood is admitted into the pulmonary artery without being ſuffered to paſs through it. Weeping begins with a great inſpiration, after which follow ſhort alternate inſpirations and exſpirations; and the ſame is finiſhed with a deep exſpiration, that is immediately joined by a large inſpiration: hence it has nearly the ſame good and bad effects; and, when moderate, is conduces to relieve the anguiſh ariſing from grief. An hickup is a very great, ſonorous, and ſudden inſpiration[79]. Sneezing conſiſts of one large or deep inſpiration, which is followed immediately with a powerful and ſudden exſpiration; and the acrid matter is blown out by it in ſome quantity from the noſtrils.

CCXC. The ſecondary uſes of reſpiration are very many. It exhales, as an emunctory, parts redundant, or even noxious, from the blood, which would ſuffocate, if they remained in the air; and the breath of many people, ſhut up in a cloſe place, impregnates the air with a ſuffocating quality. On the other hand, it abſorbs from the air a thin vapour, of which the uſe is perhaps not ſufficiently known[80]. It is by

this

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[79] In hickup, which always produces its effect by reſpiration, the œſophagus often ſuffers conſiderably; on which account much alleviation is to be hoped for, if we ſwallow any thing at different times.

[80] Among the uſes of reſpiration, ſeeing ſeveral of them are accounted of the ſame importance, may be counted the power of reſorption; by which the lungs abſorb by means of their veſſels, from the air inhaled in inſpiration, not only vapours mixed with the air, but mingle with our humours by means of the foramina, ducts, and proper canals, ſome other by far nobler parts, conſtituting at the ſame time one of the elements of the air.

This ſubſtance has got no proper name; nor do we know the nature of the part which is principally referred, in the firſt place, to the elements of the air, and, next, to our humours and blood. The once celebrated *pabulum vitæ* was an ingenious denomination, ſeeing, as has often happened, many perſons confined in narrow ſpaces, unleſs free acceſs of air is procured, have run the riſk of their life, from their wanting a proper renewal or pabu-

lum

this force that the abdomen and all its viſcera are continually compreſſed; by virtue of this, the ſtomach, inteſtines, gall-bladder, receptacle of the chyle, bladder of urine, inteſtinum rectum, and the womb itſelf, diſcharge their contents; by this action the aliments are principally ground or diſſolved, and the blood is urged

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lum, of air. But the name of *electric principle*, if we conſider the whole conſent of nature, ſeems more fitly adapted to the ſubject. For ſince the publication of the famous obſervations made by Gilbert, Guerick, Boyle, the Florentine academicians, Hawkſbee, Du Fay, Muſchenbroeck, Watſon, Ludolph, Winckler, Nollet, Franklin, Hartman, Prieſtley, and ſeveral others, both about the electricity of bodies in general, as well as of the atmoſphere in particular, the whole doctrine, by means of the new machine, the electrometer, from the expriments of Volta, Wilſon, Wilkenius, his ſerene highneſs Galitzin, Lightenberg, &c. has received ſo great additions, that it might almoſt be aſſerted, that the electric matter of the air is collected in the moſt ſimple manner by almoſt every body. From all thoſe experiments we collect,

1. That there is in the air a fluid which, in different ways, may be increaſed in one place, and diminiſhed in another; which, when collected *ſecundum artem*, exhibits electric ſparks; but, when collected in the clouds, breaks forth in lightning and thunder.

2. If from its too great congeſtion in any region of the atmoſphere or in the clouds, the circumambient air wants its due proportion, our reſpiration is leſs refreſhing, our ſtrength grows languid; but they are quickly renewed after a thunder-ſtorm, the equilibrum of the electric matter in the atmoſphere being effected, as it were, by the flaſhes of lightning.

3. Perhaps, too, we learn a method, and the remedies, by which we may artificially remove this defect; it is worth while at leaſt to conſider of this.

4. This electric matter paſſes into the blood or lymph by innumerable pores and foramina, with which the inſide of the larynx, aſpera arteria, and bronchia, abound. Upon the diverſity of theſe holes, both with reſpect to number, condition, and mucus, with which they may be covered, and to the ſize of the lungs, depends the reaſon why all men cannot inhale and abſorb the ſame quantity of electric matter from one and the ſame air.

5. It will not be eaſy for any perſon, in an affair deſtitute of ſufficient obſervation, to unravel what uſe this ſubſtance ſerves in animal bodies, and what functions depend upon it. Whether is the tone and irritability of the fibres of the body principally ſupported by it? Do the increaſe and cauſes of animal heat proceed from

urged through the ſluggiſh veſſels of the liver, ſpleen, and meſentery. It excites a kind of flux and reflux in the blood, ſo that it is alternately preſſed back towards the extremities of the veins, and a little after is propelled towards the heart by an accelerated velocity, as into an empty ſpace. Moreover, inſpiration ſerves to convey odours along with the air to the organs of ſmelling. By this, the air is mixed with the aliments; which it conduces very much to break and diſſolve towards a perfect digeſtion. But even ſucking, ſo neceſſary to the new-born infant, is made by the uſe of reſpiration, and forming a larger ſpace in the mouth, in which the air is rarefied; ſo that, by the greater preſſure of the outward air, the milk is driven into that part, where it is leſs reſiſted. Laſtly, the voice itſelf is owing to the air which we breathe; and, as it is one of the principal effects of reſpiration, we think it may be proper to give its deſcription here.

CHAP. X.

Of the VOICE *and* SPEECH.

CCXCI. THE *larynx* is the principal organ of the voice; for, that being injured, the air paſſes through the windpipe without yielding any ſound. By the larynx, we underſtand an aſſemblage of cartilages, joined into a hollow machine, which receives the air from the fauces, and tranſmits it into the windpipe, having its parts connected together by ligaments and muſcular fibres. Among theſe cartilages

from it? I think it is clear, we ought hence to ſeek the cauſe of animal electricity; which is very conſpicuous in cats, and likewiſe horſes, and many men, by the numerous ſparks which may be made to appear iſſuing from their bodies. This is perhaps the cauſe of the greater danger to which ſome men are liable of being ſtruck with thunder. The ſpontaneous burning of ſome bodies in nature are undoubtedly to be aſcribed to the ſame cauſe; and the alacrity and vigour of ſome temperaments ſurely is wonderfully increaſed by the preſence of this fluid. May this ſubſtance be joined with the acidum pingue and inflammable principle? Compare note 78.

lages of the larger kind, thoſe called the *annular* and *ſcutiform* are, in adults, frequently changed into bone. The anterior and larger part of this larynx, which lies almoſt immediately next to the ſkin, is compoſed of two cartilages; one called *thyreoides*, the other *cricoides*; to which laſt, the lateral parts of the larynx are ſo joined, that the portions of the cricoide cartilage are always ſo much larger as they are higher ſeated. The back part of the larynx is firſt made up of the ſaid annular cartilage, and then the arytænoides connected by muſcles. The epiglottis is looſely connected above the larynx with the thyreoide cartilage, in ſuch a manner, that it may be able to riſe up and ſhut down. The blood-veſſels of this part are from the upper thyreoids; and the nerves, below, are numerous from the recurrents; as above, alſo, there are nerves coming from the eighth pair variouſly inoſculating; ſome alſo from the intercoſtal. The former of theſe nerves is remarkably famous for its ariſing in the thorax, and being afterwards inflected round the aorta and right ſubclavian; and for the origin which it gives to ſome of the nerves of the heart[81], as well as for the experiment by which a ligature upon the recurrent is found to deſtroy the voice.

CCXCII. All theſe cartilages are connected by various muſcles and ligaments, with a certain degree of firmneſs, to the adjacent parts; and yet ſo that the whole is eaſily moveable together, as are alſo its ſeveral parts upon each other. Particularly the *ſcutiform* cartilage, or the thyroidea anterior, is compoſed of two plates, which are almoſt quadrangular, and inclined to each other in an obtuſe angle, which is foremoſt. Upon theſe cartilaginous plates are ſometimes found two apertures, one on each ſide for the blood-veſſels of the larynx; but they are not very often to be obſerved. The upper proceſſes of this cartilage, terminating without any protuberance, are inclined upward and backward, to their connection with the horns of the os hyoides, by ſtrong ligaments, ſometimes mixed with bone. The lower parts of theſe cartilages are ſhorter, and adapted almoſt with a flat ſurface to thoſe of the cricoide cartilage; to which they are connected with a very firm articulation, by a ſtrong and ſhort cellular ſubſtance, uniting them on each ſide. The middle parts before, being perforated with ſtrong ligaments, are connected by their inſertion to the middle of the annular cartilage; and likewiſe by other ligaments above, deſcending from the horn of the ſcutiform cartilage into the upper part of the annular cartilage.

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[81] Principally the great branch, immediately upon reflexion, aſcends behind the larynx, goes in particular to the left ſide; and having become the cardiac, deſcends towards the heart, lungs, and their veſſels. I have ſometimes obſerved two recurrent nerves in the right ſide, which on both ſides gave branches to the œſophagus, aſpera arteria, and larynx.

CCXCIII. The cricoide cartilage is before thick, and ſtrong: it is increaſed backwards, in form of a ring unequally truncated or cut through; and, in its middle part, is divided into two cavities by a protuberant line. This is firmer than the reſt of the cartilages, and, in a manner, the foundation of them: from this there are longitudinal muſcular fibres and ligaments, which deſcend into the windpipe (CCXXXVIII.) The pharynx likewiſe is connected to the ſurface of theſe cartilages by many muſcular plates, and receives the larynx as it were into its bag. From this a ſhort ligament comes on both ſides to the arytænoide cartilage.

CCXCIV. The two arytænoide cartilages are of a very complex figure, ſpontaneouſly dividing into two parts[82]. Of theſe the lower is larger; and is connected by a moveable juncture with the protuberant cricoide cartilage, by a baſis moderately hollow; and the ſame ſends a proceſs forwards, which ſeparates the glottis, and ſuſtains the inferior part of the ventricle of the larynx. They aſcend upwards, of a triangular figure, with the poſterior angle hollow, the anterior convex, divided by three furrows or ſulci, and extenuated upwards, till they are at laſt finiſhed or terminated by a pretty thick, oval, cartilaginous head fixed on them. The lower part of theſe cartilages is connected by numerous muſcular fibres, partly tranſverſe, and partly oblique; of which the different directions are viſible enough, but the ſeparation of them impracticable. Theſe are called arytænoide muſcles. In the upper part, the arytænoide cartilage departs from its companion or fellow cartilage, leaving a cleft perpendicularly betwixt them, which has been (not very properly) by ſome called the glottis.

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[82] The number of cartilages compoſing the larynx, if we ſtick to a more accurate anatomy, ſhould be changed. Five are commonly reckoned; thyroid, cricoid, two arytænoides, and epiglottis: But nine muſt be numbered. For any arytænoide, as Haller indeed has remarked, but did not chooſe to abandon the old

CCXCV. The arytænoide cartilage is connected with the thyroideal by tranſverſe ligaments, ſufficiently ſtrong and elaſtic, but covered with the common mucous membrane of the larynx, which ligaments are inſerted into the flat angle of the thyroide cartilage (CCXCII.) Theſe ligaments may be drawn out or

ſtretched

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old opinion, has a ſmall new one placed above it, larger in proportion in the larynx of ſome brutes, as the dog and horſe, which is in the ſame manner joined to the arytænoides with the aſſiſtance of a capſular ligament by means of a diſtinct articulation, as the arytænoides are connected with the cricoide. Santorinus has already named them the *ſixth* and *ſeventh*. Beſides, I obſerved a few years ago, two new cartilages, or bodies ſimilar to cartilages, which I thought ſhould be taken into the number of the parts of the larynx. Theſe cartilages lie between the epiglottis and arytænoide in any ſide, but nearer the arytænoides, above the upper ligament of the glottis. They form a round maſs, about the thickneſs of a crow quill ,and three lines long. They are extremely well ſeen, if, when the cricoide cartilage is diſſected, the poſterior part of the larynx is expanded; for then they are eaſily diſtinguiſhed riſing through the internal tunic. I think they are tolerably expreſſed in an elegant table, belonging to the third ſet of demonſtrations, which I got from my celebrated friend and anatomiſt M. Camper.

ſtretched from each other, by removing the contact of their arytænoide cartilages, and may be again conjoined by placing the cartilages one to another: and this is the true glottis, which is continuous, but at a right angle with the above-mentioned cleft (CCXCIV.)

CCXCVI. From the ſame angle of the thyroide cartilage, under a notch, from a firm ligament, and an erect ſlender ſtalk, is extended an oval cartilage, in its forepart convex, behind concave, and raiſed up in ſuch a manner, by its elaſticity, as to project conſiderably behind the tongue; but is ſo flexible or inclinable downward, whenever the root of the tongue is preſſed backward, that, by its tranſverſe poſition, it ſhuts up all paſſage into the larynx, and defends it in ſuch a manner, that whatever is contained betwixt this part, called the *epiglottis*, and the arytænoide cartilages, paſſes over downward into the pharynx. The epiglottis is conjoined to the tongue by pale membranous fibres, and to the os hyoides it is connected by many membranous expanſions. But as for muſcular fibres from the thyreo-arytænoidal and arytænoidal muſcles, it has either none at all, or elſe ſuch as are too minute to have any effect upon its elaſticity.

CCXCVII. By the ſides of the ligaments of the glottis (CCXCV.), there are two other upper and ſofter ligaments, which go out parallel from the arytænoide cartilage to the ſcutiform one, which ligaments are ſomewhat leſs tendinous and leſs elaſtic. Betwixt theſe two ligaments, on each ſide (CCXCV.), a peculiar cavity or ventricle deſcends, having the figure of a compreſſed parabolic ſinus extended downward betwixt the double membrane of the larynx, opening conſtantly with an elliptical mouth by the ſide of the glottis in the larynx[83].

CCXCVIII. Laſtly, all the internal cavity of the larynx is lined with the ſame ſoft, ſenſible, or irritable and mucous membrane, as we before deſcribed in the windpipe (CCXXXIX.) But this membrane is watered by a great number of ſmall glands. The uppermoſt are ſmall ſimple glands, aſſembled together in a heap (CCVIII.), ſeated on the anterior and convex part of the epiglottis, upon the hollow ſurface of which they ſend out various openings, large ſinuſes and productions; and others are, in like manner, continued there in ſmall hard kernels. Moreover, upon the hollow anterior ſurface and back of the arytænoide cartilages (CCXCIV.), there are ſmall glandules placed on each ſide of a looſe conglomerate fabric, compoſed of little round kernels, doubtleſs muciferous, having ſome of their looſer parts extended on each ſide as low as the annular cartilage. In the cavity of the ventricles, there are very many mucous ſinuſes. Laſtly, all the internal ſurface of the larynx is full of large mucous pores. All theſe glandules ſeparate a thin watery mucus, which yet has a conſiderable degree of viſcidity.

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[83] The ſacks or receptacles found in ſome ſpecies of apes, are not to be confounded with theſe ventricles, which may be more or leſs inflated according to the will of the animal.

CCXCIX. It may be aſked, If the thyroide glandule has a like uſe, and is of the conglomerate kind, but ſoft and lobular, with many coverings, conſiderably large or broad in its extent, but of a more tender ſubſtance than the ſalival glands, ſeated upon the thyroide cartilage, and in part upon the cricoide cartilage and windwipe, along their fore-part, ſo as to encompaſs the lateral horns and ſides of the thyroides, joined to its companion, which is narrower, by an iſthmus, which is emarginated on the lower part, but aſcending upwards by a very thin proceſs before, in its middle part, as far as the os hyoides? This gland is full of a ſerous, yellowiſh, and ſomewhat viſcid humour: but whether it emits the ſame into the windpipe or into the œſophagus, is a queſtion; at leaſt there are no ducts certainly known to open into either of them. Whether or not the juices are altogether retained in this gland, and afterwards poured into the veins in a manner reſembling the fabric of the thymus, or whether it is of the conglobate kind, is uncertain. Yet that the uſe of this gland is very conſiderable, may appear from the largeneſs of the arteries which it receives from the carotides and lower ſubclavians. The veins thereof return their blood into the jugulars and ſubclavians. It has a peculiar muſcle, not conſtantly to be found, ariſing from the edge of the os hyoides, and ſometimes from the lower margin to the left of the thyroide cartilage, which deſcends without a fellow, ſpreading its tendinous fibres over the gland. Upon which alſo the ſternohyoidei and ſternothyrodei muſcles are likewiſe ſpread or incumbent.

CCC. The whole larynx is ſuſpended from the os hyoides by the ligaments proceeding towards the ſuperior horns of the thyroide cartilage, and perfecting that cartilage from the middle of its baſis to the conjunction of its plates. The ſame, together with the conjoined os hyoides, is capable of being raiſed conſiderably, at leaſt half an inch above its mean altitude. This is performed by the biventer muſcles, together with the geniohyoidei genioglosſi, ſtyloglosſi, ſtylohyoidei, ſtylopharyngei, thyreopalatini, hyothyroidei; all or ſome of which conſpire together in that action. In this elevation the glottis is preſſed together or made narrower, and the ligaments beforementioned (CCXCV.) approach nearer together. But thus, by the aſſiſtance of the action of the arytænoide muſcles, together with the oblique and tranſverſe ones, the glottis may be accurately cloſed, ſo as to reſiſt with an incredible force the preſſure of the whole atmoſphere.

CCCI. The ſame larynx may be, in like manner, depreſſed to about half an inch beneath its ordinary ſituation, by the ſternohyoidei, ſternothyroidei, and coracohyoidei, as they are called; and, when theſe are in action, alſo by the joint force of the anterior and poſterior cricothyroidei. In this motion the arytænoide cartilages depart from each other, and render the glottis wider, which is alſo drawn open laterally by the muſcles inſerted into the ſides of the arytænoide cartilages, together with the crico-arytænoidei poſtici and laterales, and thyreo-arytænoidei: theſe may alſo compreſs the ventricles of the larynx (CCXCVII.) on which they are incumbent; the particular cartilages which make up the larynx can ſcarce be moved ſeparately.

CCCII. From the larynx the air comes into the mouth and noſtrils. By the mouth, we mean that large and irregularly ſhaped cavity between the ſoft and hard palate, both concave in the middle, and lower down parted between the muſcles which lie under, and the lower jaw. The noſtrils aſcend forwards above the ſoft palate; they are two broad cavities intercepted between the ſeptum medium, the oſſa cavernoſa, and various other bones. They are every where bony and cartilaginous.

CCCIII. The tongue lies in the middle of the mouth; and is a broad piece of fleſh eaſily changeable into any kind of figure, and thus readily moved without delay to every part of the mouth; moſt expeditiouſly directed into every ſituation, and made to aſſume any ſhape, by its own fleſhy fibres, and by the muſcles attached either to itſelf or to the os hyoides which is joined to it by many fleſhy fibres and membranes. In the fore part theſe come from the genioglоſſi and geniohyoidei muſcles; backwards from the ſtylogloſſi, ſtylohyoidei, ceratogloſſi, baſiogloſſi, chondrogloſſi, and biventer; downwards, from the ſternohyoidei and ceratohyoidei; upwards, from the ſtylogloſſi, ſtylohyoidei, from the biventers, and likewiſe from the mylohyoidei.

CCCIV. Hitherto we have given the anatomy. It remains, therefore, that we demonſtrate, what action the air produces, when it is driven by the foreſaid powers (CCLXIX, CCLXX.) from the lungs in exſpiration through the windpipe into the larynx, and from them urged out through the glottis into the mouth, variouſly configured. The conſequences or effects of this are, voice, ſpeech, and ſinging. The voice, indeed, is only formed, when the air is expelled with ſo great a velocity through the contracted glottis, that it ſplits or makes a colliſion upon the ligaments of the glottis, ſo as to put the larynx into a tremor, which tremor is returned and continued or increaſed by the elaſticity of theſe parts. Sound, therefore, ariſes from the conjunct trembling of the ligaments (CCXCV.) together with the cartilages of the larynx at one and the ſame time, which we then call the voice, and is of a peculiar kind or modulation in every ſingle claſs of animals, depending entirely upon the difference of the larynx and glottis. But when a trembling is not excited, the exſpired air cauſes a whiſper.

CCCV. The ſtrength of the voice is proportionable to the quantity of air blown out, together with the narrowneſs of the glottis; and, therefore, a large pair of lungs eaſily dilatable, with an ample cartilaginous and elaſtic larynx and windpipe, and the free echo of the noſtrils, joined with a powerful exſpiration, all conduce to this effect. But acute and grave tones of the voice, we obſerve to ariſe from various cauſes. The former proceeds from a tenſion and narrowneſs of the glottis, and the latter from a relaxation and expanſion of it. For thus, in the former, a greater number of aërial undulations are ſplit in the ſame time upon the ligaments of the glottis, whence the tremors excited at the ſame time are more numerous; but when the glottis is dilated, the contrary of all this follows. And from the greater tenſion of the ligaments, the tremors in like manner become more numerous from the ſame ſtroke. Therefore, to produce an acute and ſhrill voice, the whole larynx is drawn upwards and forwards; and ſo much the more as the voice is required to be ſharper, inſomuch that the head itſelf is inclined backwards, by which the powers of the muſcles elevating the larynx are rendered more full and effectual. The truth of this is confirmed by experience, by applying the fingers to the larynx when it forms an acute ſound; for then, to raiſe the voice an octave, you will eaſily perceive it to aſcend near half an inch. Alſo the ſame is evident from comparative anatomy, which demonſtrate the narroweſt glottis and the cloſeſt approximation of cartilages in ſinging birds, but an ample or broad glottis in hoarſe animals and ſuch as bellow or bleat. An inſtance of this we have in whiſtling, where the voice manifeſtly becomes more acute by a contraction or narrowneſs at the mouth: alſo in muſical inſtruments, in which a narrowneſs of the mouth or opening that expels the air, with a celerity of the wind blown out, are the cauſes of an acute or ſhrill tone.

CCCVI. Gravity of the voice, on the contrary, follows from a depreſſion of the larynx by the cauſes (CCCI.) already deſcribed; to which add a broad glottis and a very ample larynx. This is evident to the touch of the finger applied to the larynx when a perſon ſings, by which the deſcent of it is manifeſtly perceived to be about an inch for every octave: hence the voice of males is more grave; and hence the loweſt degrees of the voice degenerate into a muteneſs or whiſpering.

CCCVII. Is the whole difference of tone owing to the length of the ligaments of the glottis, which is augmented when the ſcutiform cartilage is drawn forward, and the arytænoide ones backward? Is it according to this rule, that the moſt acute tones are produced, which ariſe from the ligaments being exceedingly ſtretched, and thus vibrating with great celerity? This has been confirmed by repeated experiments made by eminent men; and ſome late anatomſts have obſerved, that, when the chords or ligaments of the glottis are tenſe, the peculiar voice of every kind of animal is produced by blowing air into its larynx: that this voice was more acute as the ligaments were more tenſe, and more grave as they were ſlackened; that by ſhutting the whole ligament, the voice was ſuppreſſed; by ſhutting the half, the voice was rendered an octave higher; by ſhutting a third part, a fifth higher, &c. There are not wanting, however, doubts concerning this new theory, ariſing from the cartilaginous and bony ſtructure of the glottis of birds, which of conſequence muſt be immoveable, and not extenſible; from the voice moſt cer-

tainly

tainly becoming more acute, in whiſtling, from the mere contraction of the lips; from the example of women, in which the larynx is ſofter, but the voice more acute, than in men; from experiments which ſhow, that more acute ſounds are produced by bringing the ligaments of the glottis nearer into contact with each other; from the perfect want of machines, by which the ligaments can be ſtretched, and which may bring the ſcutiform cartilage forward from the annular one. But ſeeing it appears from experiments, that a tenſion of the ligaments ſuffices for producing acute ſounds, without the contraction of the glottis, we may believe that the different tenſion of the glottis contributes more to the diverſity of voice than the different diameter of it.

CCCVIII. *Singing* is when the voice, modulated thro' various degrees of acuteneſs and gravity, is expelled through the larynx, while it is trembling and ſuſpended betwixt two contrary powers; and herein lies the principal difference betwixt the chanting of ſimple notes, and the expreſſion of words. Hence it appears to be a laborious action, by reaſon of the continual contractions of the muſcles, which keep the larynx at an equilibrium: and hence it is, that ſinging makes a perſon hot; becauſe in acute tones the narrower glottis much retards the exſpiration, while at the ſame time a great deal of air is required to give ſtrength to the voice (CCCV.); to which, again, deep inſpirations are neceſſary. Hence likewiſe the windpipe is rendered very dry, from the quicker paſſage or current of air: to prevent which, a great deal of mucus is required; and therefore it is that there are ſuch numbers of mucous receptacles in the larynx, amongſt which I am firmly of opinion the ventricles before deſcribed (CCXCVII.) ought to be numbered.

CCCIX. *Speech* is performed by the larynx at reſt, or held in the ſame place, in tones of voice differing but little in acuteneſs and gravity: but then the voice is variouſly changed or modulated by the organs of the mouth. Singing has a variation in the tone or cadence of the voice, together with a modulation of it by the organs of the mouth at the ſame time.

CCCX. All ſpeech is reducible to the pronounciation of letters, which differ in various nations; but moſt of them are alike all the world over. Of theſe, ſome are called *vowels*, which are made only by an expreſſion of the voice through the mouth, without any application of the tongue to certain parts of the mouth. But conſonants are formed by a colliſion of the tongue againſt certain parts of the mouth, lips, and teeth. But to be more particular in theſe matters is beyond our purpoſe, which does not permit us to expatiate upon the beautiful art of pronunciation. That art, as an extraordinary inſtance of mechanical knowledge, has ſo accurately determined all the corporeal cauſes concurring to each letter, that, by inſpection only, with the aſſiſtance of touch, letters pronounced are underſtood without hearing them, and the attentive perſon is thereby taught to imitate the ſame ſpeech by a like uſe of the organs[84].

CHAP.

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[84] Man's faculty of ſpeech, the prettieſt artifice of nature, ſo often exactly imitated by art, involves a double conſideration; the philoſophical, which has given riſe to that academical queſtion, particularly deſcribed in the writings of Maupertuis and Suſſmilch; and the phyſical, or rather phyſiological, which treats of the mechanical cauſe of ſpeech from the ſtructure and fabric of the parts. With reſpect to the philoſophical conſideration of ſpeech, I would nevertheleſs not totally refuſe this faculty to other animals of expreſſing themſelves by ſigns, many of which depend upon the voice: it has been very elegantly, and even in ſuch a way handled, by the learned Herder who gained the prize, Tiedman, Tetens, Zobel, Platner, and others perhaps, that a phyſiologiſt himſelf reaps a great deal of information from the reading of their works. But upon conſidering the faculty of ſpeech without regard to the parts, and comparing man with other animals; infants with adults; civilized with uncivilized nations; man educated by man, with him brought up amongſt brutes; the learned with the ignorant; the man who hears, with the deaf and dumb; it is very probable, that the elegant phenomenon of the human ſpeech as well ariſes from the proper fabric of the organs, as depends upon the degree and perfection of knowledge. For there is innate in us even from infancy a ſtruggle and deſire to expreſs the feelings of the mind by ſigns; nay, there is that deſire in all animals; with this difference only, that men, beſides the affections of their

CHAP. XI.

Of the BRAIN *and* NERVES.

CCCXI. THE remaining actions of the human body we ſhall conſider according to the courſe of the blood. The coronary arteries we ſpoke of before, when we gave the hiſtory of the heart. Next to thoſe, the carotids paſs out from the aorta.

CCCXII.

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their mind, expreſs the want of things neceſſary to their life and defence, and the impreſſions which external objects make upon the mind, by ſigns, voice, and ſpeech; which faculty, however, brutes never acquire. Infants ſignify their impatience, unleſs we ſoon underſtand their ſigns, by mournful crying. I once ſaw an Ethiopian inhabitant of Gorea weep ſeverely becauſe nobody would take notice that a certain picture was pleaſing to him. The French ſoldiers in the late war, notwithſtanding the uſual gentleneſs of that nation, were greatly diſquieted when they found their language not underſtood. Now we ſee ſpeech ſuppoſes a concatenation of various circumſtances; the perception of idea; the neceſſity of expreſſing and ſignifying it by ſigns; the organs neceſſary for performing it; and the reaſon, cuſtom, improvement, and manner of uſing the inſtrument of ſpeech in a proper way. Therefore the primary foundation of ſpeech, and of the ſtore of languages and words, conſiſts in the copiouſneſs of facts and ideas, and in the extent of knowledge and learning. The phyſical ratio of ſpeech, by which we pronounce vowels and diphthongs, according to the determined conſtriction and opening of the fauces and mouth, and according to the ſpecific alliſion of the air upon the various parts of the mouth, palate, noſtrils, and teeth, and by the percuſſion of the tongue upon the ſaid parts, it is that we form the conſonants in general, as well as thoſe paticular to ſome nations; as *th* of the Engliſh, *lr* of the Chineſe, *mr* of Malabar, elegantly ſhow; and that the mechanical application of the inſtruments of the voice and ſpeech is preciſely requiſite to the pure and diſtinct pronunciation of this or that ſyllable or word, which Wilkins before, and Vogel lately, and de Broſſe, have learnedly demonſtrated. Hence were eaſy, but not leſs learned and wonderful, the atempts not only of remedying the various vices of the voice, ſuch as Codronch and Pujat have recounted; but what merits the greateſt admiration, of teaching perſons born deaf and dumb to ſpeak artificially. The celebrated maſters of this famous art, Petrus Pontius, whether he, or, according to others, Joh. Paul. Bonetus, is reckoned the firſt inventor of this art, Wallis, Holder, Amman, Raphel, Thumig, Kerger, Arnold, &c. made uſe of a double method and principle. For ſome, from the ſimple imitations of the mouth's

changes,

CCCXII. The aorta, which comes out from the anterior part of the heart (CLVII.), in order to bend itſelf towards the vertebræ of the thorax, forms there a conſiderable arch, by which it is bent backward, and towards the left, in an angle that is round, but not very large. From the convexity of this arch, three conſiderable branches ariſe. The firſt aſcends towards the right ſide, and is immediately ſubdivided into two large arteries, of which the lowermoſt goes on in the direction of its trunk, under the denomination of the *ſubclavian*. The other aſcends according to the courſe of the windpipe to the head, and is called the *right carotid*. The *left* carotid ſprings next from the ſame arch, a little inclined to the left ſide; and the third, which is ſtill more inclined to that ſide, is called the *left ſubclavian*, which is ſomething leſs than the right. About the origination of theſe arteries, the next continuous margin of the aorta is a little thicker and more protuberant. But variations from this courſe are rarely obſerved[85].

CCCXIII.

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changes, when once a word was uttered, and the letter being marked, if they heard a proper articulation, they uſed to bring their pupils to the uſe of ſpeech with incredible patience. But others in a more natural way firſt excited the attention of their pupils to objects, ideas, affections of bodies, and whatever they wiſhed or ought to expreſs by ſpeech; then the buſineſs being made eaſier, they learn to accommodate their voice to the deſignation of ſuch things. There are examples in infants ſufficiently manifeſt, that they expreſs more eaſily the name of a thing which they have conceived in their mind, whether it has been agreeable or diſagreeable; but you will ſcarcely learn the dumb, deaf, and ſtupid, without the greateſt patience and trouble, to pronounce a ſingle letter according to the firſt method, becauſe you ought firſt to correct the dulneſs of their ſenſes and mental faculties.

[85] In more than 600 ſubjects, which I have inſpected theſe ſeventeen years paſt, with reſpect to the branches coming out of the arch of the aorta, I only obſerved five varieties: the right ſubclavian alone deſcending from the aorta, with other three from the arch; the right ſubclavian and right carotid apart from the arch, therefore four branches; again, four branches from the arch; whilſt the left vertebral and left ſubclavian deſcended from the aorta with four branches from the arch, to wit, the vertebral and left mammary; and laſtly, between five branches, I obſerved the vertebral and inferior thyroid of the left ſide came out of the arch.

CCCXIII. The carotid artery, ſurrounded with a great deal of denſe celluloſity, together with the jugular vein and nerve of the eighth pair, commonly aſcends as high as the upper part of the thyroide cartilage without ſending off any branches. There it divides into two trunks. The anterior, called the *external* carotid, which is rather larger and more in the direction of its trunk, ſends off a branch called the ſuperior *thyroidea*, alſo the inflected arteria *lingualis*, and then the *labialis*; and from the poſterior face of the carotid the next artery which ariſes is the pharyngea aſcendens, which, beſides the pharynx and muſcles of the moveable palate, ſends likewiſe a conſiderable branch in common with the nerve of the eighth pair through the foramen of the jugular vein to the dura mater, very near to the great foramen of the occiput, at the baſis of the os petroſum, and which is divided at the cuneiform proceſs of the multiform bone.

CCCXIV. Again, from the edge of the external carotid, ſprings the *occipital* artery; which ſends branches not only to the muſcles which give it a name, but likewiſe ſends a branch through a peculiar foramen of the dura mater in the angle which the os petroſum forms by departing from the mamillary portion, which artery is ſpread through the ſeat of the cerebellum; another branch paſſes over the atlas to the dura mater under or into the ſkull; and a third ſometimes goes through the foſſa jugularis to the dura mater. The next artery, which is the *auricularis*, goes to the back part of the ear, to the temple, and to the membrane of the tympanum.

CCCXV. What remains of the external carotid artery, aſcends through the parotid gland, to which having given ſome branches as well as to the face and eye-lids, it ſends out the *temporalis*, which is conſiderable. The trunk of the carotid, being inclined, conceals itſelf behind the lower jaw under the denomination of *maxillaris interna*.

CCCXVI. In that place, it directly ſends off a large trunk, which paſſes to the dura mater through a peculiar

liar opening[86] of the broad and pterygoide wings, ſeated at the middle foſſa of the brain; from whence they are largely ſpread through the temples and forehead within the dura mater, as far as the falciform ſinus. Sometimes this artery is double, and often gives out a branch that is conſpicuous to the lachrymal gland of the eye. In the ſame place, likewiſe, the maxillary artery enters the upper part of the nares by a threefold trunk, where it is ſpent after having given off the branches called *maxillares inferior* and *ſuperior* to the teeth, with the infra orbitalis to part of the face and eye-lids, and the palatina to the bone of the palate, with ſmall branches to the dura mater, and others through the ſmaller pores of the great wings, with ſuch as accompany the third and ſecond branch of the fifth pair of nerves; and laſtly, together with the dura mater, filling up the lower orbital fiſſure.

CCCXVI. But the other poſterior trunk, commonly called the *internal carotid* (CCCXIII.), aſcends without a branch. This artery having firſt made a conſiderable ſerpentine flexure enters through a peculiar foramen in the os petroſum, where it is ſurrounded with a capſule from the dura mater, like that which comes out through all the openings of the ſkull: from thence it aſcends upwards and inclined forwards, till, having penetrated into the cavity of the ſkull, it riſes up inflected and in a curvature, according to the direction of the ſella equina[87]; in the middle of which there is a cavernous or hollow ſinus retarding the blood: from thence, having given ſmall branches to the fifth pair of nerves, it ſends others to the fundibulum and dura mater, with one larger to the eye; part whereof returns again through a peculiar hole into the dura mater, which lies upon the middle of the orbit. This is the rete mirabile of beaſts, but not of man.

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[86] Commonly called the *ſpinal*, tranſmitting the arteria meningea media.

[87] In its paſſage through the canal of the os petroſum, it ſends ſome twigs, the number not conſtant, to the inner ear.

CCCXVII. But the trunk of this internal carotid paſſes over the anterior part of the ſella equina; and being incurvated backward, and received by the arachnoide membrane, giving branches to the pons and crura of the brain, with a circle to the choroide plexus, and one that accompanies the optic nerve, it then divides into an anterior and poſterior branch. The former, being conjoined with its fellow artery of the other ſide by a ſhort inoſculating branch, which ſometimes ſprings from the trunk itſelf, is then incurvated backward and upward, according to the direction of the os calloſum, and ſpreads itſelf about the middle and hinder part of the brain; where it ſometimes ſends branches to the falciform proceſs, and from the very origin of the third ventricle to the fornix and thalami. The latter, being conjoined by a ſmall inoſculating branch with the vertebral artery, unleſs that ariſes from the undivided trunk of the carotid artery, afterwards aſcends a long way upon the ſide of the brain through the Sylvian foſſa; and the ſame ſends branches to the choroide plexus. All the branches of the carotid, contained within the ſkull, are made up of more thin, ſolid, and brittle membranes, than the other arteries of the body.

CCCXVIII. But the *vertebral artery*, commonly ariſing from the ſubclavian of the ſame ſide, (though the left has been ſometimes ſeen to ſpring from the trunk of the aorta,) paſſes on without giving branches, through a place of ſecurity, till it enters a foramen in the tranſverſe proceſs of the ſixth vertebra of the neck; after which, it continues with alternate flexures to aſcend through the oblique proceſſes of the other vertebræ of the neck; from whence, at each interval, it ſends off ſmaller branches to the muſcles of the neck, and communicates with the lower thyroideal: other branches, again, ſomewhat larger, go from it backward, together with each of the nerves, to the pia mater of the ſpinal medulla; but before, the branches are larger, though leſs numerous, to the ſame ſpinal medulla, and communicate by an anaſtomoſis with its ſpinal artery anteriorly.

ly. Laſtly, growing leſs about the ſecond vertebra, and being inflected with a large curvature round the tranſverſe proceſs of the firſt vertebra, it there ſends off conſiderable branches to two of the muſcles of the neck: alſo ſmall branches it ſends off in its courſe through the great foramen of the occiput or ſkull to the dura mater, and the adjacent cavities that contain the cerebellum; after which it goes on through the ſaid foramen into the cavity of the ſkull. There aſcending, according to the courſe of the medulla oblongata, the right trunk by degrees approaches nearer to the left, and is conjoined together with it (in an extraordinary manner, hardly to be found in other parts) into an artery called the *baſilaris*, which is ſuſpended in the pia mater all along under the pons Varolii. From the vertebral arteries, before they are conjoined together, or from the trunk produced after the common manner, paſs out branches, which go to the lower ſurface of the cerebellum, and are deeply inſerted under the fourth ventricle to the inner ſubſtance of the cerebellum. Theſe ſend off the ſpinal arteries. But there are ſome inſtances where they ariſe conjunctly from a ſingle trunk; or from the trunk in one ſide, and a branch in the other. Then the baſilaris, beſides branches to the medulla oblongata and crura of the brain, gives the other lower arteries of the cerebellum. Amongſt the foreſaid branches alſo ariſes an artery, which accompanies the auditory nerve. Finally, the baſilaris, at the forepart of the pons, divides into two branches. One of theſe goes to the upper part of the cerebellum, to the fourth ventricle, to the crura of the medulla of the cerebellum, the nates, teſtes, and pineal gland: in place of this, alſo, there are two trunks. The other is divided to the loweſt part of the brain at its poſterior lobe, the choroide plexus, the plexus incumbent on the pineal gland, that gland itſelf, the thalami, corpora ſtriata, fornix, and whole anterior ventricle of the brain.

CCCXIX. From the foregoing hiſtory of the arteries belonging to the brain, it appears, that a very great quantity of blood is in every pulſation ſent to this organ, inſomuch that it makes above a ſixth part of the whole blood that goes throughout the body, and derived from trunks that are very near the heart, ſpringing from the convexity of the aorta. From hence it is probable, that the ſtrongeſt parts of the blood go to the head, and ſuch as are moſt retentive of motion. Is not this evident from the effects of mercurials exerting themſelves almoſt in the head only; from the ſudden force and action of inebriating ſpirits upon the head; from the ſhort ſtupor which camphor excites[83]; from the heat, redneſs, and ſweat, which happen oftener in the face than other parts of the body; to which add, the more eaſy eruption of volatile and contagious puſtules in the face? The well guarded paſſage of theſe great and important veſſels in their aſcent to the head, defends them from any great injury. The frequent inoſculations of one trunk, with the other going to the head, as well as the frequent communications of their branches among themſelves, leſſen any danger that might enſue from obſtruction. Hence, when the carotids are tied, the animal neither dies nor ſeems to be very uneaſy. The conſiderable flexures of the vertebral and carotid artery ſerve to moderate the impulſe of the blood coming to the brain, ſince a great part the velocity, which the blood receives from the heart, is ſpent by the various inflections. To which add, that ſome authors do not improperly obſerve that the arteries here grow larger or ſomewhat wider.

CCCXX. The hiſtory of the brain deſervedly begins from its integuments. Such a tender part, ſo neceſſary to life, we obſerve providently ſurrounded on all ſides, firſt by a ſphere of bones, conſiſting of many diſtinct portions; by which means it is rendered extenſible, at the ſame time that it is effectually guarded againſt external preſſure. To the internal ſurface of this bony ſphere, on all ſides, grows a very ſtrong membrane, compoſed of two plates ſufficiently diſtinct, which are firmly attached by an infinite number of ſmall veſſels, as by ſo many foot-ſtalks to the whole ſurface of the ſaid bones, ſo as to be nowhere eaſily ſeparable in a healthy perſon; theſe, being very thin and ſmooth, adhere leſs firmly to the bones, but more ſtrongly to the *futures*, ſo called from their figure, which join the bones of the ſkull one to another. In younger ſubjects, the adheſion of the dura mater to the ſkull is ſuch, that the ſeparation of it pulls off the fibres of the bones to which it is connected. In adults, many of the veſſels being effaced, renders it more eaſily ſeparable: yet it is not without ſome force, even in thoſe, that the dura mater can be ſeparated from the ſkull From the rupture of theſe veſſels, which enter the bones of the ſkull, appear thoſe bloody drops which are obſervable after removing the cranium. Hence appears the vanity of all that has been advanced concerning the motion of the dura mater. As to the motion which is remarked by the writers of obſervations upon wounds in this part; that, being preternatural, was the conſequence of the beating of the arteries (in a part where the reſiſtance of the bone was now removed, while the reſt of the dura mater next to the ſkull ſuſtained the force of the heart without motion); or of the brain ſwelling during exſpiration. Alſo that part, which is properly the dura mater, has neither nerves, nor ſenſation nor irritability[89].

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[83] All theſe arguments are not of the ſame force: for mercury applied in different ways to the body, produces its effect not in the head alone; ſince it occaſions in ſome a diaphoreſis, in others a diarrhœa, and in others it acts as a diuretic.

CCCXXI. The *outer plate* of the dura mater, which adheres to the bones of the ſkull, is to them inſtead of a perioſteum, and ſupplied with ſmall nerves and blood-veſſels coming through all the holes of the ſkull; from whence, and from its coheſion with the peri-

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[89] That nature has given none, or, what is liker truth, very few nerves to the dura meninges, I am convinced from Lobſtein's and my own obſervations; however, both inflammation and ſurgical phenomena forbid my denying, that this membrane is totally deſtitute of ſenſibility.

perioſtea of the head, ſpine, and whole body, it has received the name *mater*. The *internal plate* of the dura mater is in moſt parts continuous with the former: but, in ſome ſubjects, it recedes a little from it, as in the great ſphenoidal wings; and at the ſides of the ſella equina, where a good deal of blood is poured betwixt them; and they likewiſe recede thus upon the ſella equina itſelf: the ſame plate having left the outermoſt, adhering firmly to the bones of the ſkull, deſcends doubled together to form the falx, which ariſes firſt from behind the proceſſus criſtæ galli of the multiform bone, afterwards from the criſta itſelf, and from the whole junctures of the bones of the forehead and the parietals; and laſtly, it ariſes from the middle of the back part of the occipital bone, and, growing broader backwards, is interpoſed betwixt the hemiſpheres of the brain; the more remote part of it forward hangs over the corpus calloſum, and that which is next in the back-part is extenuated to an edge in the ſame place. That there are ſhining fibres in this part, diſperſed towards the longitudinal ſinus from the conjunction of the tentorium, in the ſhape of branches and palm-twigs, is certain; but it does not therefore follow that they have any muſcular motion; and betwixt theſe fibres frequently there is no membrane, only natural foramina are interpoſed. The falx is both joined to, and continued from, the middle tentorium, which is extended laterally. In the ſame manner, with ſome difference of ſituation, the ſaid falx ſends out a ſhort plate downward, which divides the cerebellum, together with the ſtrong tentoria or lateral productions; which ariſing from the cruciform protuberance of the occiput, are interpoſed tranſverſely betwixt the brain and cerebellum, extended as far as the limits of the os petroſum, and connected to the anterior clinoide proceſſes, leaving an oval aperture for the medulla oblongata to deſcend freely. Theſe productions of the dura mater ſerve to prevent the parts of the brain from preſſing one another, in all ſituations and poſtures of the body; and they likewiſe hinder one part of the brain from bruiſing the other, by any ſhock or concuſſion. Hence it is, that in the more active quadrupeds, where a concuſſion is more likely to happen, the brain and cerebellum are divided by a bony partition.

CCCXXII. In the external ſurface of the pia mater, not far from the ſinus of the falx, are placed ſmall glandules, ſeated in the reticular texture of the hard membrane, partly looking towards the ſinus, to whoſe cavity they are oppoſed, in ſuch a manner, that ſome of them are contiguous to the hollow of the ſinus; others are ſo placed at the inſertion of the larger veins into the pia mater, that, together with the former, they make up a continued range or ſeries; ſome are alſo obſerved in the tentorium of the cerebellum, which are ſometimes ſoft, oval, and white, ſometimes red, hard, and in appearance like wrinkles[90]. But the vapour, which exhales from the ſurface of the pia mater, is not ſeparated by theſe glands: for it is every where exhaled, even into the ventricles, where there are none of thoſe glandules; and it plentifully tranſpires every where from the mouths of the leaſt arteries, as we ſee by experience, when water or fiſh-glue are injected, which ſweat out through every point in the ſurface of the dura mater.

CCCXXIII. The next covering of the brain, which is more cloſe to it, and preſſes the whole ſurface of the brain, as that does the cavity of the ſkull, has been denominated from its tenuity, *arachnoides*, i. e. like a ſpider's web. This very thin or tender membrane, being pellucid like water, every way ſurrounds the brain, whoſe inequalities it climbs over, and according to its extreme thinneſs is pretty ſtrong, and ſurrounds the larger veſſels in ſuch a manner, that the ſaid veſſels ſeem to run between the pia mater and arachnoides; which laſt

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[90] So called glands by Pacchioni; frequently found in great numbers between the two layers of the dura meninges, for the moſt part in the duct of the falciform ſinus; they occupy a broad ſurface: their uſes are not yet ſufficiently known; they belong rather to the conglomerate, than to the conglobate glands.

laſt is, therefore, no part or lamella of the pia mater, from which it differs by ſituation, and is connected to it by a cellular texture after the manner of the ſpinal marrow, although it is reſolved into a cellular nature between the hemiſpheres of the brain.

CCCXXIV. The third or innermoſt covering of the brain, which is ſoft and cellular, is properly the *pia mater*[91]. This immediately inveſts the whole ſurface of the brain and ſpinal marrow on all ſides, is tender, and made up of a vaſt number of ſmall veſſels which are joined together by a cellular texture: but theſe veſſels it ſends into the brain in a regular order, like little roots. This deſcends betwixt every furrow and fiſſure of the brain and cerebellum, and even inſinuates itſelf into the ſpinal medulla, and is the bond by which the little protuberances of the brain are joined together. This being received into the cavities of the brain, changes its fabric, ſo as to become ſoft and almoſt of a medullary conſiſtence, more eſpecially when the ſubject that comes under the examination of the knife has lain dead ſome conſiderable time, yet then it is eaſy enough to demonſtrate the veſſels themſelves in its fabric.

CCCXXV. The *veins* of the brain are not diſpoſed in the ſame manner with thoſe in other parts of the body. For neither have they any valves, nor do they run together in company with the arteries, nor have their trunks the ſtructure which is commonly obſerved in the other veins. The veins, therefore, which come out of the innermoſt cavities of the brain, thoſe which are ſpread upon the ſtriated bodies, the veins of the choriode plexus, with the lucid ſeptum and the anterior ventricles, are collected together into trunks which at laſt meet in one great vein, or often two, which, being accompanied with many ſmall arteries of the choroide plexus, deſcends backward to the partition of the brain and cerebellum. In that place, it receives veins ariſing from the poſterior and lower part of the brain, and ſome of the cerebellum, from whence the blood paſſes into a ſinus, which is a kind of vein included in a reduplication of the inner plate or membrane of the brain, into which the veins, to ſhorten their length, are generally inſerted; and this ſinuous vein generally deſcends to the greater ſinus on the left ſide, though ſometimes it ends bifurcated, one branch on each ſide. This is called the *fourth* ſinus.

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[91] Deſerving the name of *vaſcular membrane*, ſince there is no membrane found in the body ſo fully ſupplied with veſſels.

CCCXXVI. The upper and ſuperficial veins of the brain are large, and ſpread in the windings with which the brain on all ſides abounds. With thoſe veins, thro' the whole ſurface of the brain, are inſerted other veins of the dura mater; and others, which enter by peculiar orifices into the falciform ſinus. From thence the veins, gradually collected together, paſs along, moſt of them forward, ſome few of them in a ſtraight direction, and others backwards; of which thoſe forward are the largeſt, and open themſelves, their extremities being obliquely cut off, into the long *falciform ſinus* which is formed by the right and left plate of the internal membrane of the dura mater, which meet together below upon the upper part of the back of the falx. From thence it is of a triangular figure, convex in its upper ſide, beginning with a ſlender origin at the ſeat of the foramen cæcum, that is placed above the criſta galli; from whence it aſcends and follows the courſe of the falx until that joins the tentorium: it is generally inclined to the right ſide, and takes the name of the *right tranſverſe ſinus*, which then goes by a peculiar channel in the occipital and temporal bone, tranſverſely to its incurvation at the opening of the jugular vein; in which place being much enlarged, it receives the lower ſinus petroſus, together with the occipital ones, which are hereby diſcharged into the jugular vein. But the left tranſverſe ſinus reſembles the former; and is, like that conveyed in a ſimilar courſe to the jugular vein, into which it is rather inſerted on the right ſide, than continued as it were in a trunk. Into it the fourth ſinus (CCCXXV.), together with the occipital one, uſually inſert themſelves. But there are ſome inſtances, where all theſe are diſpoſed in a different manner, by an inſertion of the longitudinal into the left tranſverſe ſinus; and then the right tranſverſe ſinus receives the fourth and the occipital one. At other times it is equally divided into two tranſverſe trunks; and ſometimes the middle ſinus joins the tranſverſe ones. The two ſinuſes alſo have been found ſimilar and parallel to each other.

CCCXXVII. There is a ſlender and rounder ſinus, which runs along the lower and thicker margin of the falx, ſomewhat of an irregular figure, more reſembling a vein, receiving veins from the falx itſelf, and communicating likewiſe with the upper ſinus; it alſo receives veins from the adjacent hemiſpheres of the brain, and from the corpus calloſum. Where the tentorium joins with the forepart of the falx, this is commonly there inſerted into the fourth ſinus.

CCCXXVIII. The *lower veins* of the brain which lie next to the baſis of the ſkull, are variouſly inſerted. The foremoſt of them coming from the foſſa ſylviana, collected together into ſome trunks, are inſerted into the cavernous ſinus, or triangular interval, that lies at the ſide of the ſella equina, betwixt the external and internal plate of the dura mater. Other veins, from the pons itſelf, lead into the upper ſinus petroſus. Other poſterior veins, which come from the poſterior lobes of the brain, are inſerted in great numbers into the tranſverſe ſinus that is ſeated within the tentorium.

CCCXXIX. The upper veins of the cerebellum meeting together in large trunks, partly open themſelves into the fourth ſinus, and in part into the tranſverſe ſinus. The lower veins from the cerebellum and medulla oblongata, inſert themſelves into the upper ſinus petroſus; the later alſo into the tranſverſe proceſs very near the place where it goes out.

CCCXXX. There are many ſinuſes, beſides thoſe before-mentioned. The moſt anterior of them, which is commonly *like a circle*, is larger behind than in its fore-part, which is ſlenderer, and ſurrounds the pituitary glandule betwixt the clinoide proceſſes, communicating with the cavernous and with the lower petroſe ſinuſes; likewiſe communicating betwixt thoſe proceſſes and the carotid artery, and again, by the way of the ſixth pair, with the upper petroſe ſinuſes behind the fifth nerve. There are ſome inſtances where this ſinus receives the ophthalmic vein; and ſometimes the tranſverſe, joining to the cavernous ſinus, ſupplies the place of this circular ſinus, or elſe is preſent with it at the ſame time.

CCCXXXI. The *upper petroſe ſinus* is conveyed backwards in a cavity of the os petroſum, and takes its origin from the extremity of the anterior ſulcus of the os petroſum, where it communicates with the cavernous ſinus, and receives the inſertions of the veins of the dura mater, and ſometimes of the anterior veins of the brain itſelf, mentioned before (CCCXXVIII.); then it is inſerted into the angle of the tranſverſe ſinus, where it begins to be bent; ſometimes alſo it joins the inferior ſinus of the os petroſum. Another vein, likewiſe deſcending by the os petroſum, is in like manner inſerted into the angle of the tranſverſe ſinus. The *lower ſinus petroſus*, which is larger, goes round the root of the bone of this name, and communicates with its fellow behind the clinoide proceſs; alſo twice it communicates with the cavernous ſinus, and with the upper ſinus, and is conjoined under the nerve of the fifth pair, being finally inſerted into the jugular foſſa or cavity. Moreover, it receives ſome veins of the dura mater from the baſis of the vertebræ. To the ſame outlet alſo the *occipital ſinus* leads on each ſide, which being pretty large, goes round the margin of the foramen, till arriving at the falx of the cerebellum (CCCXXI.), it is ſooner or later inſerted together with its fellow, for the moſt part into the fourth ſinus, and with that into the left tranſverſe one, or into the longitudinal ſinus itſelf, or laſtly by a divided extremity into each of the tranſverſe ſinuſes. This ſinus receives the lower and poſterior veins of the dura mater, and ſome others from the vertebræ.

CCCXXXII. The *anterior occipital ſinus* is irregular or multiform, partly tranſverſe, and partly deſcending to the great foramen, being variouſly conjoined with the lower petroſe ſinuſes: from whence it paſſes with the nerves of the ninth pair; and either communicates through a peculiar foramen, by emiſſaries into the outer vertebral vein; or other branches, going downwards, open into the venous circles of the ſpinal medulla. But the *cavernous ſinus* of the dura mater (CCCXXV.), being ſurrounded with a good deal of cellular ſubſtance, receives, beſides the forementioned ſinus (CCCXXIX, CCCXXX), large veins already deſcribed; alſo the ophthalmic, and principal vein of the dura mater; and tranſmits them with peculiar veins, together with the firſt and ſecond nerve, and third branch of the fifth pair, with a large artery of the dura mater (CCCXVI.) and the internal carotid (CCCXVI.): alſo it ſends out other emiſſaries through a foramen, which is not conſtant in the great wing, which form inoſculations with veins placed on the outſide of the ſkull leading to the jugulars, and eſpecially with the largeſt pterygoidal plexus of veins belonging to the noſe. In the ſame manner, the veins of the pericranium paſs through ſmall holes in the parietal bones into the longitudinal ſinus, as the occipital veins paſs through the maſtoide hole into the tranſverſe ſinus through the anterior channel of the occipital bone, and the external vertebral veins are inſerted into the jugular ſinus; and others of the anterior occipital veins accompany the nerve of the ninth pair. Thus there are an infinite number of ways open to the blood; by which it may paſs from the ſinuſes, wherein it is often collected in too great quantity by various directions, according as the part is more lax or has a greater declivity. Hence no violent ſymptoms follow upon tying either or both of the jugulars or other large veins.

CCCXXXIII. The great quantity of blood which goes to the brain, the greater impulſe with which it is ſent into the carotid arteries (CCCXIX.), and the ſecurity of this part from every kind of preſſure by a ſtrong bony fence, joined with the ſlower motion of the blood through the abdominal viſcera and lower extremities, alſo the perpetual exerciſe of the brain and ſenſes, do all determine a copious flux of blood to theſe parts, and ſome other cauſes ſerve to fill the head ſurpriſingly with blood. Hence it is that a redneſs of the face, a turgeſcence and ſparkling of the eyes, with a pain and pulſation or throbbing of the arteries in the head, are ſo frequently followed with a bleeding at the noſe, by violent exerciſes or motions of the body. From hence, therefore, it is evident, that if the veins were of a thin and round ſtructure in the brain, they would be unavoidably in greater danger of breaking, and conſequently apoplexies (to which, in their preſent ſtate, they are often liable) would be much more frequent. To avoid this, therefore, nature has given a different figure to the veins which carry out the blood from the brain, by which they are more eaſily and largely dilatable, becauſe they make an unequal reſiſtance: their texture is likewiſe very firm, and more difficultly broken, eſpecially in the larger ſinuſes, which perform the office of trunks; for as to the ſinuſes of the leſſer ſort, they are either round, half cylindrical, or of an irregular figure. Beſides this, nature has guarded the ſinuſes by croſs-beams, internally made of ſtrong membranes, and detached from the right to the left ſide within the ſinus, which in greater diſtenſions they draw towards a more acute angle, which is capable of a larger dilatation, ſtrengthening and guarding it from a rupture at the ſame time She has likewiſe, in theſe veins, provided numberleſs inoſculations, by which they open mutually one into another, and openly communicate with the external veſſels of the head and with thoſe of the ſpinal medulla, by which means they are capable of freeing themſelves more eaſily whenever they are overcharged with blood, (CCCXXXII.)

CCCXXXIV. It is by ſome queried, Whether a part of the arterial blood is not poured into the ſinuſes of the brain; and whether they have not a pulſation excited from that blood? That they have no pulſation, is paſt doubt; becauſe the dura mater every way adheres firmly to the ſkull, but much more firmly in thoſe parts which are the ſeats of the ſinuſes. Indeed they receive liquors injected by the arteries; but whether thoſe tranſude through the ſmall exhaling arterial veſſels, or whether they firſt make a complete circle through the veins, as indeed is much more probable, we are not yet furniſhed with experiments enough to determine.

CCCXXXV. Thus all the blood of the brain is finally conveyed into the jugular veins, which are very dilatable, and for that reaſon guarded with valves to prevent a return of the venous blood from the right auricle, being at the ſame time ſurrounded with a good deal of cellular ſubſtance. As to the blood which goes from the head to the vertebral veins, it is a very inconſiderable quantity; but the jugulars anſwer in ſuch a manner to the great upper vena cava in a direct courſe, that they afford the highway for the blood to return back to the heart. The branches of theſe are commonly the ſame with thoſe of the brain; namely, the veins of the brain, and thoſe of the face.

CCCXXXVI. The external jugular is a cutaneous vein of the neck, which produces the temporal one, and is united with the internal jugular at the baſis of the lower jaw; and the ſame ſends a branch through the os maxillare into the tranſverſe ſinus. The internal vertebral empties itſelf through the tranſverſe proceſſes of the neck into the tranſverſe ſinus as often as the canal belonging to it is opened.

CCCXXXVII. The two lateral ſinuſes of the ſpinal marrow run along its whole length, are joined to each vertebra by a ſemicircular arch, and at laſt are united with the jugular and occipital ſinuſes: they ſend branches, however, to the ſpinal marrow, joined with the anterior and poſterior ſpinal vein.

CCCXXXVIII. The veins form innumerable anaſtomoſes with one another, that the blood may return with the greateſt eaſe from the head, of which the repletion is very dangerous. The brain is alſo more eaſily evacuated in the time of inſpiration, and ſubſides as we ſee when the ſkull is opened, but ſwells during the time of exſpiration. Hence, blowing the noſe, ſneezing, and coughing, aredangerous to thoſe whoſe brain is ſwelled by retained blood.

CCCXXXIX. Whether or not there are lymphatic veſſels to be ſeen in the brain, is by ſome queſtioned. Indeed, we read deſcriptions of them in the pia mater, and in the larger choroidal plexus; but, for my own part, I have never been able to ſee them, and poſſibly there are none to be ſeen, ſince there are no conglobate glands in the brain, which are always near at hand wherever any of theſe veſſels are to be found[92]. As for the various accounts which are given of the pituitary glandule, of the infundibulum, and of the ducts which lead from thence into the veins of the head, abſorbing and tranſmitting a water from the ventricles of the brain, they are not ſupported by anatomical experiments: which makes it more probable, that the vapour which is ſecreted into the ventricles of a healthy perſon is, in like proportion, abſorbed again by the inhaling veins; or, if any part abounds, that it deſcends through the bottom of the ventricles to the baſis of the ſkull, and from thence into the looſe cavity of the ſpinal medulla. That this is the caſe, appears from palſies which enſue on one ſide of the body after apoplexies; and from

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[93] In almoſt no viſcus has the exiſtence of lymphatic veſſels been oftener aſſerted and again denied, than in the brain. Although, indeed, I am fully certain, that a group of lymphatic glands is nowhere found without lymphatic veſſels, by no means, however, could I aſſert, that there are nowhere lymphatic veſſels where glands do not appear. By analogy drawn from the whole body and all the viſcera, I am lead to think, that the brain is not deſtitute of its aqueous veſſels, and that they run in particular upon the ſurface, not in the heart of its ſubſtance, although I myſelf have never ſeen any, but thoſe moving on the choroid plexus towards the tentorium, and on the inner ſurface of the dura mater, in the duct of the ſuperior longitudinal ſinus. But I cannot diſcredit the induſtry of the celebrated Sommering, who confirms the obſervations of King, Collins, and Pacchioni, who ſaw them going upon the pia mater. I would aſk, May they be joined with the glands of Pacchioni? May theſe corpuſcles ſupply the place of lymphatic glands?

from the bifid ſpines or watery tumours in the lower part of the ſpinal medulla, following in thoſe who have an hydrocephalus.

CCCXL. It now remains for us to ſpeak of the encephalon itſelf[93]. But many are the parts included under this general denomination. By the *brain*, properly ſo called, we underſtand that upper and ſoft viſcus which is contained in the ſkull, and which is lodged by itſelf in its fore part; but backward it is incumbent over another conſiderable part, called the *cerebellum*, which lies in the poſterior and lower cavities of the occipital bone, under the membranous tentorium, which parts it from the brain. Its lower, middle, and white portion, deſcending before the cerebellum, is in part called the *pons*, and in part the *medulla oblongata*.

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[93] The brain, under which name we comprehend the cerebellum, crura, pons, and medulla oblongata, has it in common with all the viſcera, that, according to the diverſity of age, the condition and mutability of functions, in the various claſſes, genera, and ſpecies of animals it has its proportion, which varies prodigiouſly, to the body. Nobody will queſtion that the functions of the mind, the ſenſual faculties, and the more eaſy or difficult riſe and impreſſion of ideas, both occaſioned by theſe laſt agents, as well as by cuſtom and imitation, owe a dependence upon this different proportion of the brain to the reſt of the body. The dignity of ſuch diſquiſitions, and a peculiar fondneſs and deſire towards medical pſychology, prompted me, theſe eighteen years, whenever an occaſion preſented, in different animals, and in more than three hundred human ſubjects, to make inquiry in determining the proportion of the parts of the brain to one another and to the reſt of the body, and that of man to various brutes, paying regard to the weight as well as to the ſpecific gravity. Since the year 1766, I have ſeveral times communicated to my hearers, both in my medico-pſychological, and particularly anatomical lectures, many obſervations, both upon the weight and the increaſe of the medullary and diminution of the cortical ſubſtance, and likewiſe the increaſed ſpecific gravity of the brain. Hence many of my thoughts, my name, however, ſuppreſſed, were copied and inſerted in various philoſophical deſcriptions; but ſome errors crept in amongſt them: to amend which, I ſhall ſoon inſert a compendium of my obſervations, ſince the proper tables, containing more than 500 experiments, do not ſuit this place. Haller has given a great catalogue of the weight of the brain and its proportion to the whole body, and containing the weight of ſeveral animals, taken from Schneider, Pozzi, Paris Tranſactions, the famous Buffon, Chalder, &c. but my obſervations will come in more properly, chap. xvii.

CCCXLI. The *figure* of the brain reſembles that of half an egg, which is deeply divided longitudinally, but not cut through above half way, into hemiſpheres reſembling the fourth part of an egg. Both the upper and lower ſurfaces are full of many gyri or convolutions, which pretty deeply cut or divide the brain with round ends or angles into undulated portions. But the largeſt is that which aſcends on both ſides outwards from the ſides of the ſella turcica, and divides the hemiſphere into two lobes. Upon the ſurface of the ſaid lobules or portions lies the *cortex*, extremely ſoft, and inclined from a yellow or red to a grey or aſh colour, being the moſt tender of all parts in the human body: this inwardly is filled with the *medulla*, which is almoſt perfectly white, but redder in the fœtus; in many places, it is perforated by red arteries, which are more ſimple and perpendicular, or ſtraight, than in other parts. This medulla is more ſolid and more capable of ſuſtaining its figure, notwithſtanding it is very ſoft, and abounds in a greater quantity than the cortex[94]. The greater poſterior branch of the carotid artery (CCCXVII.) firſt divides the right and afterwards the left hemiſphere of the brain into an interior lobe, which is the larger; and a poſterior lobe, which is the leſs.

CCCXLII. The fabric of the cortex has been a long time controverted; but it is now ſufficiently evident, from anatomical injections, that much the greater part of it conſiſts of mere veſſels, which are every way inſerted from the ſmall branches of the pia mater, detached like little roots into the cortical ſubſtance, and conveying a juice much thinner than blood in their natural ſtate, although in ſome diſeaſes, and by ſtrangling, they often receive even the red parts of the blood, more eſpecially in brutes and birds. The remaining part of the cortex, which is not filled by any injection, is probably either an aſſemblage of veins, or of yet more tender veſſels; for no other diſſimilar parts are apparent in the cortex, whilſt it is in an entire or natural ſtate; from whence one may conjecture ſome part of it to be tubular, and the other part ſolid. As to glandules making the fabric of the brain, that notion has been diſcarded by univerſal conſent; nor indeed has there been any other opinion received with leſs probability than this.

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[94] Whoever accurately inſpects the human brain, will find a threefold ſubſtance, particularly in ſuch brains as have been indurated by a mixture of alchohol and nitrous acid.

CCCXLIII. In order to gain a knowledge of the nature of medulla, we are to conſider the anatomical ſtructure of this part of the human brain, compared with the brains of brute animals and fiſh. Therefore this part of the brain, which follows immediately under the outer gyri or convolutions of the cortex, is of a white colour, and becomes gradually broader and more abundant; ſo that, at length, it makes up the whole oval ſection of the brain, except only the gyri in the ſurface, which makes the cortex. In this part, the two hemiſpheres of the brain, as before obſerved, are divided but half way through; which hemiſpheres here continue their coheſion with the medulla in the middle. That part of the medulla which is extended under the falciform proceſs, but at ſome diſtance from it, is called *corpus calloſum;* in the ſurface of which run two parallel white ſtripes, formed by the pulſation of the arteries: theſe ſtripes diverging forwards, and terminated at the place where they mingle together in the fore-part, are thence divided backwards. But the anterior extremity of this callous body is loſt in the ſubſtance of the crura, coming from the anterior lobes of the brain: the poſterior, which is broader, with a ſhorter curvature in the ſhape of a nail, is brought inwards; and the other column deſcends into the inferior horn of the ventricle, whence it is continued along with the longer one into the hippocampus. Moreover, the whole ſurface of this callous body is ſtreaked with tranſverſe fibres, which are continued, but extenuated, into the next adjacent medulla of the brain itſelf. Even the interior ſubſtance of this body is of a ſtriated nature, and its lower ſurface has its ſuture and fibres tranſverſe.

CCCXLIV. As to the remaining parts of the brain, a ſcrutiny is more difficult to be made into them: for the brain is not a ſolid body, but begins to be hollow internally from the lower part of its medulla, which is incumbent upon the multiform bone, at which place the greater crus of the brain paſſes out from it; and in this cavity the medulla is only covered with the pia mater, which aſcends backward, and then turning continues its courſe forward and upward. Next, the brain divides itſelf near the poſterior extremity of its callous body; and, at the ſame time, ſends one of its ſhorter poſterior portions into the poſterior lobe of the brain, turning its extremity inwards. But the anterior portion is continued a long way by the ſide of the callous body, parallel to the horizon; and turning its horn outward, which there grows broader, it is terminated in the anterior lobe of the brain. This cavity, of which there is one in each hemiſphere of the brain [95], is called its triangular or anterior *ventricle;* and it is naturally filled with a vapour, which is frequently condenſed into water or jelly.

CCCXLV. This cavity is full; ſo that the upper and lower parts of the brain meet together. The lower ſide or pavement of this part is variouſly figured. In its forepart, it forms a horn; below which there is a riſing moderately convex, and of conſiderable length, diverging backwards, covered with a membrane that is extremely vaſcular; and, being outwardly of an aſh or grey colour, is called the *corpora ſtriata;* becauſe inwardly they exhibit to the view, together with much cortex, alternate white oval ſtreaks, parallel to one another, longer on the back part; beſides, as it were, leſſer me-

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[95] It is quite joined under the margin of the lower fornix, ſo that water and mercury, injected from the one cavity into the other, has a free tranſition.

medullary ſpots and micæ. More inwardly and backward, there are two other ſimilar eminences, more of an egg-like ſhape, towards the third ventricle and other parts, moſtly cineritious on the outſide, obſcurely ſtriated, and ſo incumbent together, that they frequently cohere on the upper part, where they are confounded with the cortex: and theſe, continuing their courſe through the horn of each anterior ventricle, deſcend to the baſis of the ſkull, and there generate the optic nerves, of which they are called the *thalami*. Betwixt the ſaid ſtriated bodies and thoſe thalami, lies an intermediate, parallel, white, and ſtreaked medullary portion, called the double ſemicircular centre, produced from the *anterior commiſſure*, and frequently from the crura of the fornix; but eſpecially from the medulla itſelf, before the thalami of the brain. This commiſſure is broad, ſtrong, and joins together the anterior part of the brain before the thalami. The double centre, which is broadeſt behind, ariſes with many fibres, from the junction of the foot of the hippocampus with the medulla of the brain. But the corpora ſtriata, with the thalami, conſtitute the medullary crura of the brain; which, in the baſis of the cerebrum, lie over the medulla of the cerebellum, and are joined together at the extremity of the bridge above-mentioned. At the place where they approach neareſt to one another, each ſends out an hemiſpherical mamillary eminence. The fibres of the medulla of the brain itſelf, mixed together with the medulla of the cerebellum, deſcend into the medulla oblongata; and, being then collected into a bundle, they go to the corpora pyramidalia.

CCCXLVI. It is to be obſerved, that the corpus calloſum medium projects or riſes up in the common axis or middle of thoſe ventricles. Behind, this body lies contiguous and incumbent on the fornix; but, before, there are two ſimilar medullary partitions, which deſcend from this body the whole length of the corpora ſtriata; and this part, which in its middle includes an anonymous cavity, goes under the name of *ſeptum pellucidum*[96]. This ſeptum is continued to the *fornix;* that is to ſay, the four-horned medullary trabecula, which takes its anterior origin from the medulla of the brain, and ſometimes from the mamillary protuberances, and the commiſſure which we have mentioned; and behind that, particularly under the thalami, and often from the double centre and crooked line of the thalami. This fornix is incumbent upon an interval of the ſtriated bodies, and upon another interval of the thalami: from whence it degenerates partly into a broad thin fimbria; and partly into another tubercle, which is evidently continuous with the fornix and callous body of an half cylindrical figure, and furniſhed with an appoſite *fimbria.* Theſe deſcend into the lower anterior horns of the ventricles; and at laſt terminate outwards by a ſort of convex ſulcated end, imprinted by the gyri of the brain; and terminated by a foot, having as it were four-furrows, whence the name of *hippocampus*, which externally are covered by exceeding thin medullary plates, but are inwardly of a cortical ſubſtance. At the beginning of the diviſion of the foot of the hippocampus, the tænia ends in two white ſtriæ, a long and a ſhort one, inſerted into this foot and into the brain, or one inſerted into the inmoſt part of the unguis. A like protuberance is continued in the poſterior horn of the ventricle, crooked inwards at its extremity like the claw of a bird, to which a continuous column occupies the hinder part of the baſis of the horn of the deſcending ventricle, which is continued with the corpus calloſum. Betwixt the departing poſterior crura of the fornix, the medullary portion, which is behind the middle plexus of the ventricles, and painted with tranſverſe and palmated ſtreaks, is called the *pſalterium* or harp.

CCCXLVII. Within the anterior or lower part of each

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[96] This cavity, which I uſe to call *ventriculum ſepti lucidi*, communicates with no other ventricle of the brain. I have ſeen it wonderfully dilated in an internal hydrocephalus, containing two drams of fluid.

each of the ventricles, begins the vaſcular *plexus*, called *choroides*, included in the pia mater only, it lying naked in the reſt of the cavity of the ſkull, made up of a great many ſmall arteries CCCXVII, CCCXVIII.), together with little veins originating from the larger trunk (CCCXXV.); all which numerous veſſels, joined together by the pia mater, reſemble a curtain variouſly folded. With theſe are intermixed many ſmall pellucid glandules of a round figure, reſembling hydatids. It aſcends from the baſis of the brain, through the deſcending horn of the ventricle, and thus is dilated as it goes upward; but, thence, becoming narrower, it goes on with the optic thalamus, to the poſterior extremity of the ſeptum lucidum. When thoſe plexuſes have reached the anterior extremity of the thalami, being afterwards reflected and united together into one very large vaſcular plexus, they gradually deſcend through the crevice of the third ventricle as far as the pineal glandula, and then are continued into the pia mater of the poſterior lobes of the brain. From this plexus, doubtleſs, proceeds the internal warmth of the brain, with its exhalation and inhalation. But the choroidal plexuſes become very broad where the anterior ventricles of the brain begin to deſcend; and thence, contracting gradually downward, they project their extremities to the ends of the anterior ventricles, covered only with the pia mater.

CCCXLVIII. Betwixt the thalami, applied one to the other almoſt with a plain ſurface, there is a natural fiſſure terminating the crura of the brain, which meet together in the baſis of the ſkull; and this is called the *third ventricle*. It leads by a declivity, like a funnel, forward into a concave column; which though hollow in brutes, is yet evidently leſs tubular in man, and connected to the pituitary glandule.

CCCXLIX. This is compreſſed on both ſides, ſimple, of uncertain ſtructure; on the anterior part almoſt round, and of a reddiſh colour; on the poſterior, cineritious,

ritious, broad tranſverſely, covered with the pia mater of the brain: it lies upon the proper impreſſion of the ſella turcica, and ſeems to be a kind of appendix to the brain.

CCCL. Backward, the thalami are conjoined together in the bottom of the ventricle, by a medullary faſcia, or poſterior commiſſure, and by a ſmaller tranſverſe chord; from which a crooked white ſtreak goes out on both ſides in the upper part, which loſes itſelf in the double centre, in the anterior commiſſure, and ſometimes in the crus of the fornix. On the fore and upper part, the thalami ſpring out of a protuberance, which is formed by the triangular fornix lying between the two thalami.

CCCLI. This little eminence ſeparates the upper triangular cavity of the third ventricle, filled up with the fornix, from the inferior calamus ſcriptorius, in ſuch a manner, that the cavity is continued both from the anterior and poſterior extremity of the third ventricle, from the top to the bottom. But even the anterior commiſſure is a medullary ſtreak which unites the thalami before the anterior crura of the fornix.

CCCLII. Again, behind the thalami, thoſe tranſverſe figured eminences of the medulla meet together, which conjoin the medulla of the right and left poſterior lobes of the brain. In this part, backward, are cut out four oval eminences, which are outwardly ſmaller, called the *nates* and *teſtes*, and which are of a ſubſtance inwardly cortical, but outwardly medullary. Upon theſe is ſeated a cortical glandule, ſomewhat oval and conical, ſpread with many ſmall veſſels, into which the choroide plexus here degenerates: this is the *pineal glandule* ſo much celebrated, and ſo frequently diſeaſed, and joined to the brain by ſmall foot-ſtalks ſent into the linea alba thro' the thalami in their paſſage forwards Between this eminence, on which theſe four protuberances are cut out, and the crura of the oblong medulla, paſſes a groove or channel in the ſame direction from the third to the

fourth

fourth ventricle, manifeſtly open, reſembling an aqueduct [97].

CCCLIII. The whole medulla of the brain is, in its lower part or baſis, collected together into two very thick compreſſed columns, diſtinguiſhed in their ſurface by a line running according to their length; which have internally a cortical ſubſtance, and are the *crura of the brain.* Theſe, meeting together backwards, are covered by the ſubjacent crura of the cerebellum, and are inſerted by apparent ſtrata of fibres into the pyramidal bodies of the medulla oblongata; and with the other deeper fibres, which ſeparate the inner tranſverſe fibres that come from the cerebellum from the preceding, meet together with the medulla cerebelli to make up the beginning of the medulla oblongata.

CCCLIV. The *cerebellum*, as it is leſs, ſo it is more ſimple than the brain. It has two lobes, but no where deeply parted, united above and below in their centre to a ring of the ſame fabric with itſelf, called the *vermis*, at the ſide of which there is a ſmooth eminence of the ſame nature with the cerebellum itſelf. This part of the encephalon contains a great deal of the cortex, with a leſs proportion of medullary ſubſtance. And here likewiſe, the cortex is placed in the circumference, but marked with gyri or convolutions, which are rather parallel to each other, ſo as to form circles. Thus the ſmall lobules or portions are diſtinguiſhed, but not deeply, and afterwards ſend out each of them their medulla; which is, by degrees, ſo collected together in rays or branches, meeting in one trunk, that the whole reſembles the figure of little trees. This medulla, collected together into the large crura of the cerebellum, and marked in the inner part with ſerrated cortical lines, interwoven with one another, hath a threefold termination. One part aſcends towards the baſis of the nates, where it joins with the medulla of the brain under the teſtes; but the right and left parts of it are joined to each other by a tranſverſe medullary ſtria behind the nates. From this, ſome diſtinct fibres aſcend outwards, and join themſelves to the tranſverſe ones of the bridge. Between theſe firſt proceſſes of the cerebellum, is ſtretched a medullary lamina, behind the fourth ventricle, ſending forth fibres beyond the proceſs. Another portion deſcends into the ſpinal medulla, and terminates in peculiar nail-like protuberances, which are each anonymous, and have other cortical portions near them. A third portion, which is larger, and ſinuated in the middle, goes tranſverſely downward under the crura of the brain, which it embraces; and by twice intermixing alternately with their tranſverſe medullary fibres (CCCLII.), it is in a great meaſure confounded together with them.

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[97] So called by Sylvius, as the jugum itſelf, under which runs the pons Sylvii.

CCCLV. Thus is produced from the crura of the brain deſcending above thoſe of the cerebellum, and from the medulla of the cerebellum tranſverſely ſurrounding that of the cerebrum, the *pons*, at firſt almoſt oval, but more blunted on both ſides, depreſſed in the middle, and inſcribed on all ſides with tranſverſe fibres. Then the *medulla oblongata*, continuous to the pons, is internally variegated and ſtreaked with a ſubſtance like the cortex, and deſcends of a conical ſhape, inclined to the great foramen in the occiput. This medulla has two pair of tubercles before the pons; the outermoſt of the figure of an olive, and the innermoſt of a pyramidal ſhape, for they leſſen downward like a cone; and theſe are immediately divided by a ſulcus, through which the pia mater enters. But betwixt that medulla and the worm-like proceſs of the cerebellum, is formed a cavity, limited by the four leſſer proceſſes, which as they aſcend or deſcend is at firſt narrower; but above the tubercle (CCCLIV.) it grows broader, and is of a rhomboidal figure: it is called the *fourth ventricle*. It is ſhut in its back-part by the valvula magna, or a medullary velum, uniting the proceſſes going from the cerebellum to the nates and vermis, and tranſverſe ſtria lying under the teſtes, and ſhutting the ventricle behind,

behind (CCCLIV.) This ventricle has a moderately large ſulcus or furrow, having ſwelled lips on each ſide inſcribed on the medulla oblongata, and anſwering to the canal that is covered by the nates and teſtes, called the *aqueduct* (CCCXLVIII.) In this laſt ventricle, as well as in the foregoing, is lodged the plexus choroides, only leſs in bulk, together with an upper ſulcus called *calamus*. Each of theſe ſulci is continued down along the medulla ſpinalis, both in its anterior and poſterior ſide; more evidently in the former, but leſs ſo in the latter. Tranſverſe fibres are detached in its upper part from the right to the left ſide, both of the medulla oblongata and ſpinalis. But two or three of the tranſverſe ſtreaks that ariſe from the eminences which intercept a ſulcus, are inſerted into the ſoft part of the acouſtic nerve; others go to the eighth pair, and others of the ſame kind aſcend to the crus of the cerebellum.

CCCLVI. All the medulla of the brain and cerebellum goes out from the ſkull, through particular openings, to the parts to which it is deſtined. The ſmaller bundles of this medulla we call *nerves;* but the larger, deſcending through the ſpine, we call the *medulla ſpinalis*, which is a continuation of that called *oblongata* (CCCLV.) But the nerves, which are bundles of the medulla, and very ſoft in their origin, are compoſed of ſtraight parallel fibres in diſtinct threads. Theſe nervous cords, after they have gone forward ſome length, covered with the firm pia mater of a reddiſh colour, are afterwards united into a more tough or permanent ſtring; and then, conjoined, divided, and in the neighbourhood of others like themſelves, they haſten through a cellular texture to their proper opening in the dura mater, and thence run down through the intervals of the channels formed by that membrane, till they meet with an opening in the ſkull, out of which they paſs through the membranous funnel of the dura mater. The nerve, having arrived without the ſkull, is commonly ſurrounded by the dura mater, ſo as to become very ſolid and firm. Thus it is in the optic nerve, in the fifth pair, and in others; but in ſome again there does not appear to be any dura mater ſurrounding the nerve, as in the olfactory nerves, in the ſoft portion of the auditory nerve, and the intercoſtal. The nerves now deſcend naked or leſs fenced betwixt the muſcles, detaching their cords or threads of which they are compoſed, and are ſtill made up of the medulla covered by the pia mater. Many ſmall threads of this kind are joined together into larger, by the union of the cellular ſubſtance that ſurrounds them, through which run many ſmall arteries and veins intermixed; and ſometimes fat itſelf is therein lodged. But in general the outer covering, common to the whole nervous bundle, is either derived from the dura mater, or at leaſt is a hard plate of the cellular ſubſtance, wherein all the ſmaller threads are contained and united into one nerve, often reſembling a true membrane.

CCCLVII. It is common to all the nerves of the head to ariſe and paſs out from the lower part of the medulla of the brain or cerebellum[98]. The *olfactory nerve* ariſe

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[98] The real origin of the nerves of the brain is placed now beyond diſpute, ſince the elegant tables of Santorinus and of the learned Sommering were publiſhed, with which the celebrated Camper agrees in his Tables. which are not yet come out, and with Mayer alſo. Nature herſelf has divided all the nerves in the animal body into three claſſes; the firſt of which contains the nerves, whoſe origin is from the brain, coming through the foramina of the cranium: I ſimply call theſe the nerves of the cranium. The ſecond comprehend the greater number of thoſe ſent from the ſpinal marrow, which I call ſpinal nerves: and the third contains only a few, which are compoſed of others, and might be called mixt, if there was need of a particular name. To this belongs the acceſſorius, which is a true ſpinal one; the great ſympathetic, a very complicated nerve; and the phrenic and ſplanchnic. Nobody will call in queſtion the limits and attributes of the ſpinal nerves ſince the time of the greata natomiſt Baron de Aſch; but it is certain, that the real number of the nerves of the firſt claſs was not determined before the famous Sommering, who firſt devulged the opinion of his maſter. For indeed, if we conſider, without regard to the parts, the riſe, nature, deſcent, and termination of the portio dura of the ſeventh pair, then the proper pair of nerves, we ought to make the eighth there, and to diſtinguiſh it by the name of *communicans faciei*. All which are next in order, be-

with lateral fibres from the interval betwixt the anterior lobe of the brain, but with direct fibres from the medulla of the anterior lobe itſelf. A great part of the *optic nerve* ſprings from the thalami (CCCXLV.), but ſome part likewiſe from the crus of the brain, while the nerves decuſſate through its ſubſtance. The third ariſes from the loweſt crus of the medulla of the brain behind the mammillary bodies. The fourth, which is either ſimple or trifid, ſends a proceſs from the ſide of the cerebellum to the teſtes. The fifth ariſes plainly from the peduncles of the cerebellum itſelf[99]. The ſixth out of a ſulcus (CCCLIV.) deep from the bottom of the pons betwixt that and the medulla oblongata. The ſeventh ariſes with one part ſofter from the medulla oblongata, and by two tranſverſe ſtriæ, from the fourth ventricle itſelf; and with another part harder from that portion of the crus of the cerebellum which lies next the pons[100]. The eighth nerve ariſes from the interval betwixt the olivary and pyramidal bodies or protuberances; and, according to the obſervation of other eminent anatomiſts, from the fourth ventricle likewiſe. The ninth ariſes from the corpora olivaria and pyramidalia. The tenth, by reaſon of its double root, is reckoned a nerve of the neck, going out with an arch, in company with the upper and lower adjacent nerve.

There

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long to the medulla oblongata; the firſt pair of which is the gloſſopharyngæus; ſecond, the vagus; third, the lingualis medius, and then begin the pinales, furniſhed with a double root and ganglion; the firſt of which is the celebrated pair of Aſch, denominated the *tenth* by Willis.

[99] By my experiments it conſiſts evidently of a double portion; the minor or anterior, compoſed of from 4 to 6 nervous faſciculi, and ariſing from the upper and high part of the foot-ſtalk; the greater, or poſterior and inferior, made up of 34 to 50 faſciculi, and riſing from the middle line of the foot-ſtalk; a deſcription of which I inſerted in the Gottenburg Commentaris, as well as the famous anatomiſt Sommering.

[100] There are three portions of nerves, which are commonly taken in under the ſeventh pair: *a*, the communicans faciei, or the portio dura, which we may alſo call the ſmall ſympathetic; *b*, a new intermediate portio; *c*, the auditory or acouſtic properly ſo called. They are clearly repreſented by my ingenious pupil Sommering, Tab. 2.

There is, therefore, no nervous branch that ariſes properly from the cerebellum, unleſs it be the fifth: for the anterior nerves, the olfactories, optics, and third nerve, come from the brain only; and all the reſt from thoſe parts where the medulla, both of the brain and cerebellum, is conjoined.

CCCLVIII. The *ſpinal medulla* is a kind of very ſoft medullary rope or appendix to the encephalon, continued down from the medulla oblongata, as low as the ſecond vertebræ of the loins. In the neck its anterior and poſterior ſides are flat, laterally convex, but in the back it is ſquare. It is largeſt where it goes out from the head; from thence it is ſmaller in the top of the neck; in the lower part it is larger; but ſmaller again through almoſt the whole back; thicker in the lower, oval, and conical part of it; and laſtly it ends in tubercles. The pia mater is a proper integument to this part as well as to the brain, ſince it enters the foremoſt fiſſure deeply, and divides the medulla almoſt into two. The cortical ſubſtance which lies within it is obſcure. It has an anterior artery produced in the ſkull, from the branches of the vertebrals. This artery is retrograde, and deſcends through the whole length of the pia mater, perpetually making alternate ſinuous flexures, which form inoſculations about many but not all of the nerves, with branches of the vertebral, intercoſtal, lumbar, and ſacrolumbar arteries; till at laſt, being covered with a peculiar coat from the pia mater, it goes out and diſappears at the coccyx. In like manner the two poſterior arteries, which are leſs, ariſe and are diſtributed from the lower arteries of the cerebellum, and are more ſerpentine, and frequently inoſculated among themſelves. The ſpinal veins deſcend, together with the arteries, from the brain itſelf, ſending out branches in like manner on each ſide, which accompany the nerves like ſo many circular ſinuſes, fixed in the dura mater, and correſponding to the number of the vertebræ; all which ſo communicate one with another, that each has on all ſides a direct conſent both with the uppermoſt and lowermoſt; and, after having ſent out branches that join the vertebral, intercoſtal, and lumbar veins, they unite with thoſe of the ſacrum. The uppermoſt of theſe ſinuſes inoſculates with the anterior occipital ſinuſes (CCCXXXII.)

CCCLIX. But there is another covering, not ſpread with any veſſels, which ſurrounds the ſpinal medulla looſely and at a diſtance, and is pretty firm, of a watery clearneſs, called *arachnoides;* and which being longer than the pia mater, is extended to the bottom of the os ſacrum, where the nerves, only deſcending from the medulla, are collected by it into a faſciculus. But in what manner it goes out, together with the nerves, has not hitherto been deſcribed. Between that membrane and the dura mater there exhales a vapour, which is frequently condenſed into a reddiſh water, and produces a true dropſy.

CCCLX. Laſtly, the *dura mater*, belonging to the ſpinal medulla, and continued from that of the cerebellum, ſurrounding the arachnoides, and from thence deſcending to the bottom of the os ſacrum, being larger at its beginning, at the bottom of the neck, and at the loins, but ſlenderer in the back, and being connected ultimately by many ligaments to the os ſacrum, it at laſt diſappears in a ſlender cone. As the nerves paſs out through this membrane, it gives them an external covering; and directly thickens or ſwells with them into a *ganglion*, or hard, oval, reddiſh-coloured knot. To this hard covering of the dura mater internally adheres a ligament denticulated at the interval of each of the nerves, which ariſes from the ſkull near the courſe or paſſage of the ninth pair of nerves, tying the arachnoides to the dura mater by triangular productions in each of the intervals of the nerves, and betwixt the anterior and poſterior bundles of the ſpinal nerves down to the bottom, and twelfth vertebra of the back. Externally there is a ſort of fat ſurrounds the dura mater, and alſo lines internally the covering of the vertebræ of the ſpine; which by this means are ſo adapted like a tube to the medulla ſpinalis, that the latter is not liable to be compreſſed by the bending of it in any poſition.

CCCLXI. The fibres of the ſpinal medulla, in dropſical ſubjects and in brute animals, appear very diſtinct. Theſe medullary fibres go out from the whole anterior and poſterior ſides of this long appendix; after which, the anterior cords are commonly wrapt up in the pia mater, in which they converge together like rays into a larger faſciculus; to which alſo join ſimilar threads in another bundle from the poſterior faſciculi joining together into one nerve, which, paſſing out through the holes of the dura mater, produces a nerve betwixt each two vertebræ. Theſe vertebræ are about 30 in number. In the neck, numerous radiated nervous fibres compoſe one large and almoſt tranſverſe nerve. In the back they deſcend, in general, of a ſmaller ſize; but ſo that the lower and larger ones are commonly joined cloſe to one another. The large and long lumbar ones join to form the cauda equina. The loweſt nerves of the os ſacrum are the leaſt, the uppermoſt ones large. Many of the dorſal nerves, together with the lumbar ones, and thoſe of the os ſacrum, covered with their proper membrane from the pia mater, accompanied with their arteries, and incloſed in the arachnoides, make up that rope which is called the *cauda equina*.

CCCLXII Thoſe nerves are afterwards diſtributed to all parts of the body in a manner very complex, and not here to be deſcribed. But we muſt not omit to obſerve, that all the ſpinal nerves, except one or two in the neck, have both an anterior and poſterior trunk. This is only ſent to the muſcles. It produces a nervous root; which joining the other adjacent nerves, and having given a ſmall circle that proceeds from the ſixth nerve of the brain and the ſecond branch of the fifth, comes through the pterygoide canal, and forms one of the principal nerves of the human body; which, communicating with almoſt all the other nerves of the whole ſyſtem, ſends out nervous branches to the heart and all the viſcera of the abdomen. The ſame has as many ganglia as roots from the medulla, unleſs where many of them join into one ganglion. It communicates in various places with the crural, brachial, and diaphragmatical nerves, alſo with the par vagum and ninth pair of nerves. The other primary or capital nerve is the eighth or *vague nerve*, ariſing from the brain, and joining itſelf to the intercoſtal in the bottom of the neck, in the thorax, and in the abdomen: this paſſes out of the ſkull in three cords; of which the larger ſends branches to the larynx, gula, lungs, and the cardiac plexus itſelf (XCIX), alſo to the œſophagus, ſtomach, and liver. The third of theſe is the *phrenic nerve*, ariſing from moſt of the lower nerves of the neck and arms; and ſometimes, being increaſed from the root of the ſpinal nerve, it deſcends by the ſide of the pericardium, and inſerts itſelf into the upper face of the diaphragm; but below it receives nerves from the great plexus of the intercoſtal nerve. Laſtly, the *acceſſory nerve*, ariſing by many ſmall roots from the ſix or ſeven uppermoſt poſterior nerves at the neck, and from the medulla oblongata, joins the nerve of the eighth pair going back again into the ſkull, and ſeems, by this means, to make a conſent betwixt that important nerve and the ſpinal medulla. Moreover, the nerves of the limbs have at their origin plexuſes or knots, and are, on account of their length, harder and firmer in their ſubſtance, and much larger, than the great nerves which go to the viſcera: thoſe which go to the hand, ariſe from the four lower nerves of the neck and firſt of the back; but thoſe of the lower extremity from the nerves of the loins and os ſacrum.

CCCLXIV. The nerves divide into branches like the blood veſſels, but in acute angles, and often in a courſe manifeſtly retrograde, growing gradually ſofter and leſs in bulk, though ſometimes they become thicker as they recede from the brain, till at length their ultimate extremities, which are ſeldom viſible, ſeem to terminate in a pulp, by depoſiting the firm integuments with which they were covered, after the manner which we obſerve in the optic nerve. But the rectilineal courſe of the fibres, continued from the brain itſelf, is ſuch, that it is never broken off by the diviſion or ſplitting of a nerve into ſmaller threads, which only recede from each other by an opening of the cellular ſubſtance that tied them together. This appears from the diſorders, which are determined not to all, but only to ſome ſingle parts by injuries of the brain; as a loſs of the voice, deafneſs, dumbneſs, and palſies of particular muſcles[101]. They are connected in their courſe by the cellular ſubſtance to the adjacent parts, but have hardly any elaſticity; whence they do not fly back after being divided, but only expel, by the contraction of their integuments, the ſoft medulla which they include. But though they are irritated ever ſo much, they are neither contracted, nor are they rendered ſhorter during the motion of the muſcles which they produce. A great many nerves are ſent into the muſcles[102]; many of them go to the ſkin; but fewer to the viſcera, and feweſt of all to the lungs[103]; none at all to the dura and pia mater, arachnoides, tendons, capſules, and ligaments, and laſtly the whole ſecondary membranes. They make frequent inoſculations with each other, or one trunk gives off many branches: and principally from the conjunction of theſe branches the nervous ganglia are formed; i. e. hard nervous tumours, for the moſt part repleniſhed with blood-veſſels, and included in a firm membrane, but of a uſe and ſtructure as yet not certainly known, in which the ſtraight courſe of the nervous fibres is interrupted. The nerves of the ſenſes alone are excepted from theſe ganglia or knots, together with the eighth pair; but they ſeem in a manner eſſential to the phrenic nerves, to the fifth pair, to thoſe of the limbs, to the ſpinal and to the intercoſtal nerves, which laſt are truly ſpinal nerves.

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[101] The want of ſmell, ſight, and hearing, is incurable, if the nerves are compreſſed or deſtroyed by tumours, ſcirrhi, and in particular venereal ulcers, ariſing in that part of the brain where the nerves come out.

[102] More nerves manifeſtly enter the organs of ſenſe than the muſcles.

[103] It is very certain that the lungs are ſupplied with more nerves than the ſpleen, uterus, and other viſcera.

CCCLXV. Thus far we are taught by anatomy concerning the brain and nerves; it now remains only that we explain the phyſiological uſes of theſe parts. Every nerve, therefore, that is irritated by any cauſe, produces a ſharp ſenſe of pain. But we muſt reckon the mind to be changed, when any change happens to the body. It is the medullary part of the nerve which feels the pain. If the nerve was endued with any peculiar ſenſe, that ſenſe periſhes when the nerve is compreſſed or diſſected: the ſenſes of the whole body are loſt by a compreſſion of the brain; and of thoſe parts whoſe nerves originate below the ſeat of preſſure, if you compreſs the ſpinal marrow. If certain parts of the brain are compreſſed from which particular nerves ariſe, then thoſe ſenſes only are loſt which depend on the nerves, as the ſight or hearing. Thoſe parts of the body which receive many nerves, as the eyes and penis, have the moſt acute ſenſation; thoſe have leaſt ſenſibility which receive few nerves, as the viſcera; and thoſe which have no nerves, as the dura mater, tendons, ligaments, ſecundines, broad bones, and cartilages, have no ſenſation.

CCCLXVI. It is therefore evident, that all ſenſation ariſes from the impreſſion of an active ſubſtance on ſome nerve of the human body; and that the ſame is then repreſented to the mind by means of that nerve's connection with the brain. But this ſeems to be falſe, that the mind perceives immediately by means of the ſenſoria and branches of the nerves. For this opinion is refuted, by the pains felt after amputation, the ceſſation of all pain when the nerve is compreſſed, and the deſtruction of the ſenſes by diſeaſes of the brain. And that the effect of the ſenſes is preſerved in the brain, is evident from the loſs of memory which follows when the brain is injured or compreſſed; alſo from the delirium which happens in ſome diſeaſes, and the ſtupor and ſleepineſs which happen in others. We have already obſerved, that the dura mater has no ſenſation.

CCCLXVII. Another office of the nerves is to excite motions, even the moſt violent ones, in the muſcles. When a nerve is irritated, the muſcle to which it goes is immediately convulſed; or if it ſends branches to ſeveral muſcles, they are all convulſed at the ſame time. This happens during the life of the animal, and a little after its death, while all the parts are moiſt. By a great irritation other muſcles are thrown into convulſions, and afterwards the whole body. Nor is it neceſſary that the nerve ſhould be whole; for even when it is cut, an irritation of it will excite ſimilar motions in the muſcles. On the other hand, when a nerve is compreſſed or tied, a palſy follows; for the muſcles which have their nerves from that one lie unmoved, when they are commanded by the will to act. They alſo recover their motion when the compreſſion is removed, provided the nerve has received no hurt.

CCCLXVIII. But the medulla of the brain being vellicated or irritated deeply in its crura, dreadful convulſions enſue throughout the whole; and this without any exception, whatever be the part of the brain ſo affected; nor is there any difference in the brain, cerebellum, or corpus calloſum. The ſame conſequences alſo follow, if the ſpinal medulla be irritated. But if the encephalon itſelf be compreſſed in any part whatever, there follows thence a loſs of ſenſe and motion in ſome part of the body, which muſt be the part whoſe nerves are detached from the affected or compreſſed quarter of the brain. This is clearly evidenced from experiments which have been made on particular parts of the brain diſordered: as from thoſe, for inſtance, in which the origin of the nerves is compreſſed, the voice is loſt; or the motion of one arm or leg, or one ſide of the pharynx, is aboliſhed. But in the injuries of the ſpinal medulla, it is ſtill more evident, that thoſe parts which receive their nerves ariſing from the place injured in the medulla, are either convulſed, if that be irritated, or rendered paralytic, if it be compreſſed. But when any more conſiderable or large portion of the brain ſuffers a compreſſure, either from blood, water, ſcirrhus, an impacted bone, or other mechanical cauſes, the greateſt part, and then the whole, of the body loſes its power of motion; of thoſe organs which obey the will when the malady is in a leſſer degree, and of them all when it is greater; all which diſorders ceaſe upon removing the compreſſing cauſe. Laſtly, if the ſpinal medulla, entering the neck, be injured, death immediately follows; becauſe from thoſe parts principally ariſe almoſt all the nerves of the heart (XCIX.)

CCCLXIX. Theſe things being conſidered, there ſeems to be no doubt, but the cauſe of all motion in the human body ariſes from the brain with its annexed cerebellum and ſpinal marrow; and that it thence proceeds through the nerves to all the muſcular parts of the body. The cauſe, therefore, of this motion cannot reſide in the parts themſelves, becauſe otherwiſe the moving cauſe would continue to act after being ſeparated from the brain; nor would it be increaſed by irritating the brain, or weakened by a compreſſure of it.

CCCLXX. Whether or not is there in the brain any principal part, in which reſides the origin of all motion, the end of all the ſenſations, and where the ſoul has its ſeat? Whether is this proved by the frequent obſervation, that the ſenſes are ſometimes entire, and that motion likewiſe remains, though the brain is grievouſly hurt? Is it in the corpus calloſum? Or is this ſhown by the greater fatality of wounds or diſeaſes in the corpus calloſum? Is this body ſufficiently connected with the nerves? Are there any experiments which deduce from thence the fifth, ſeventh, and other nerves? Doth not the ſame or even greater mortality of wounds in the medulla ſpinalis prove the ſame thing? Yet this is not the ſeat of the ſoul, ſeeing, though it is compreſſed or even deſtroyed, the perſon will ſurvive a long time with the perfect uſe of all his ſenſes. Nay, this opinion is oppoſed by very many facts: birds have no corpus calloſum;

ſum; and wounds in that body are not in the leaſt more mortal than thoſe in other parts of the brain, as appears from undoubted experiments.

CCCLXXI. But the power of the cerebellum is not greater in exciting the vital motions, nor are the vital and animal functions diſtinct; nor does the cerebellum produce the nerves of the heart and of other vital organs, and the brain thoſe which go to the organs of ſenſe and voluntary motion. From the cerebellum the fifth nerve is moſt evidently produced; but that goes to the tongue, pterygoide, buccinator, temporal, and frontal muſcles, the lap of the ear, the eye, the noſtrils; all which are parts either moved by the will, or deſtined for ſenſe. Again, the ſame nerve, like the eighth, ſends vital branches to the heart and lungs, animal and voluntary ones to the larynx, and ſenſitive ones to the ſtomach. Again, it is not even true, that diſorders of the cerebellum bring on ſo certain and ſpeedy death. For certain experiments, even of our own making, ſhow that it has borne wounds and ſcirrhi, without taking away life; nor is it much different from the brain, only that it is ſofter and more tender; and laſtly, we have known, and that not very rarely, wounds of the cerebellum cured. The power, however, of this part, in exciting convulſions, is ſomewhat greater.

CCCLXXII. Concerning the ſeat of the ſoul, we muſt inquire experimentally. In the firſt place, it muſt be in the head, and not in the ſpinal marrow. For though this is obſtructed, the conſtancy of the mind remains the ſame. Again, it appears, from the experiment of convulſions ariſing, when the inmoſt parts of the brain are irritated, that it lies not in the cortex, but in the medulla; and, by a probable conjecture, in the crura of the medulla, the corpora ſtriata, thalami, pons, medulla oblongata, and cerebellum. And again, by another not abſurd conjecture, where the origin of every nerve lies, as the firſt origins of all the nerves taken together make up the ſenſorium commune. Are the ſenſations of the mind repreſented there, or do the voluntary and neceſſary motions ariſe in that place? This ſeems very probable. For it does not ſeem poſſible, that the origin of motion can lie below that of the nerve; for although it ſhould be aſſumed gratis, that ſome part of the nerve is immoveable, or inſenſible, yet that is altogether ſimilar to the remainder of the nerve. Nor can the origin of motion (CCCLXIX.) depend upon the arteries, which have neither the faculty of ſenſation nor that of voluntary motion. It therefore follows, that the ſeat of the mind muſt be where the nerve firſt begins its formation or origin.

CCCLXXIII. We come now to explain the manner in which the nerves become the organs of ſenſe or motion; which, as it lies hid in the ultimate elementary fabric of the medullary fibres, ſeems to be placed above the reach both of ſenſe and reaſon; but we ſhall, notwithſtanding, endeavour to make this as plain as experiments will enable us. And firſt, it is demonſtrated, that the ſenſation does not come through the membranes from the ſentient organ to the brain, nor that motion is ſent through the coverings from the brain into the muſcle. For the brain itſelf lies deeper than theſe membranes, and receives the impreſſions of ſenſe, and when hurt throws the muſcles into convulſions. Moreover, it is certain, that the nerves ariſe from the medulla of the brain; the truth of which is manifeſt to the eye in all the nerves of the brain, more eſpecially in the olfactory, optic, fourth and ſeventh pair of nerves, which continue their medullary fabric a long way before they put on the covering of the pia mater.

CCCLXXIV. We muſt, therefore, next inquire into this medulla, what it is. It is a very ſoft pulp, harder in inſects and fooliſh animals; but every where ſimilar to itſelf. It affects, however, to be formed into fibres or parallel threads, lying upon one another lengthwiſe. That the compoſition of it is fibrous, appears from innumerable arguments; more eſpecially to the eye in the corpus calloſum, in the ſtriatum, and thalami of the optic nerves; but ſtill more evidently in the brains of fiſh, and eſpecially in their thalami optici[104]. Again, that the fibres of the brain are continuous with thoſe of the nerves, ſo as to form one extended and open continuation, appears, by obſervation, very evidently in the ſeventh, fourth, and fifth pair of nerves. There is a great deal of oil in the medulla, upwards of a tenth part of its whole weight.

CCCLXXV. But here a controverſy begins concerning the nature of this fibril, which with others of the like kind compoſes the ſubſtance of the medulla and of the nerves. That this is a mere ſolid thread, and only watered by a vapour exhaling into the cellular fabric which ſurrounds the nervous fibres, has been aſſerted by many of the moderns; but that, when it is ſtruck by a ſenſible body, a vibration is excited, which is then conveyed to the brain.

CCCLXXVI. But the phenomena of wounded nerves will not allow us to imagine the nervous fibres to be ſolid. For if an irritated nerve is ſhaken, (and that happens after the manner of an elaſtic cord, which trembles when it is taken hold of,) the nerve ought to be made of hard fibres, and tied by their extremities to hard bodies: they ought alſo to be tenſe; for neither ſoft cords, nor ſuch as are not tenſe, or ſuch as are not well faſtened, are ever obſerved to tremulate. But all the nerves, at their origin, are medullary, and very ſoft, and exceedingly far from any kind of tenſion: where they paſs through channels, where they are well guarded, they retain the ſame ſoft texture, and are not covered with membranes, as in the intercoſtal nerves and the ſecond nerves of the fifth pair: ſome alſo are ſoft throughout their whole length, whatever ſize they may be of; for example, the ſoft olfactory and acouſtic nerves, from which we would moſt readily expect a tremor, as in the caſe of ſound. Again, though the nerves are hard, they

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[104] In no part of the brain does the fibrous nature of the medulla more evidently appear than in the fornix, immerſed in nitrous acid for ſome continued time; for then I could divide it into the moſt ſubtile fibres.

they are ſoftened in the viſcera, muſcles, and ſenſoria, before they exert their operations. Therefore, the nervous fibres cannot poſſibly tremulate in an elaſtic manner, neither at their origin, nor where they are tenſe. But the ſame, even in the proper and moſt favourable caſes, cannot tremulate; becauſe, through their whole length, they are firmly tied to the ſolid parts by means of the cellular fabric; for example, the nerves of the heart are tied to the great arteries, and to the pericardium. Finally, that the nerves are deſtitute of all elaſticity, is demonſtrated by experiments, in which the nerves cut in two neither ſhorten nor draw back their divided ends to the ſolid parts; but are rather more elongated by their laxity, and expel their contained medulla in form of a protuberance. Again, the extreme ſoftneſs of the medulla in the brain, with all the phenomena of pain and convulſion, leave no room to ſuſpect any ſort of tenſion concerned in the effects or operations produced by the nerves.

CCCLXXVII. Add to this, that the force of an irritated nerve is never propagated upward, ſo as to convulſe the muſcles that are ſeated above the place of irritation. This is a conſequence altogether diſagreeing with elaſtacity; for an elaſtic cord propagates its tremors every way, from the point of percuſſion to both extremities. But if neither the phenomena of ſenſe nor motion can be explained from the nature of elaſticity, the only probable ſuppoſition that remains is, that there is a liquor ſent through the brain, which, deſcending from thence through the nerves, flows out to all the extreme parts of the body; the motion of which liquor, quickened by irritation, operates only according to the direction in which it flows through the nerve; ſo that convulſions cannot thereby aſcend upwards, becauſe of the reſiſtance made by the freſh afflux of the fluid from the brain. But the ſame liquid being put in motion in an organ of ſenſe, can carry that ſenſation upwards to the brain; ſeeing it is reſiſted by no ſenſitive torrent coming from the brain in a contrary direction.

CCCLXXVIII. It is therefore probable, that the nervous fibres, and the medullary ones of the brain, which have the ſame nature, are hollow. Nor is the objection which ariſes from the ſmallneſs of theſe tubes, not viſible by any microſcope, of any force againſt the propoſed arguments; to which add the abſence of a ſwelling in a tied nerve, which, in reality, is not ſufficiently true; with other arguments of the like kind, which indeed ſhow the weakneſs of the ſenſes, but have not any validity againſt the real exiſtence of a juice or ſpirit in the nerves. If they are tubes, it is very probable that they have their humours from the arteries of the brain.

CCCLXXIX. But concerning the nature of this nervous liquid, there are many doubts. Many of the moderns will have it to be extremely elaſtic, of an etherial or of an electrical matter; but the more reaſonable part make it to be incompreſſible and watery, but of a lymphatic or albuminous nature. Indeed it is not to be denied, that we have many arguments againſt admitting either of theſe opinions. An electrical matter is, indeed, very powerful, and fit for motion; but then it is not confinable within the nerves, ſince it penetrates throughout the whole animal to which it is communicated, exerting its force upon the fleſh and fat, as well as upon the nerves. But, in a living animal, the nerves only, or ſuch parts as have nerves running through them, are affected by irritation; and, therefore, this liquid muſt be of a nature that will make it flow through, and be contained within, the ſmall pipes of the nerves. And a ligature on the nerve takes away ſenſe and motion, but cannot ſtop the motion of a torrent of electrical matter[105].

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[105] There is certainly no phyſiological diſpute, in which, without regard to the parts, a more difficult deciſion can be offered, than that important queſtion, How do the nerves act in the bodies of animals? The doctrine of the nervous fluid, or animal ſpirits, is confirmed by many arguments drawn from anatomy; but is fully refuted by as many, if not more, of a ſimilar nature. But ocular demonſtration of

CCCLXXX. A watery and albuminous nature is common to moſt of the juices in the human body, and may be therefore readily granted to the juice of the nerves; like the water which exhales into the ventricles of the brain from the ſame veſſels; alſo, from the example of a gelatinous or lymphatic juice, which flows out in cutting through the brain in fiſh, and the nerves of larger animals; to which add, the tumour which ariſes in tied nerves. But are theſe properties ſufficient to explain the wonderful force of convulſed nerves, obſervable in the diſſections of living animals, and even in the leſſer inſects, with the great ſtrength of mad and hyſterical people? Whether or no is not this difficulty ſomewhat leſſened from the hydroſtatical experiments of attraction in ſmall tubes; which although it may explain the ſtrength and motion, is neverthelеſs inconſiſtent with the celerity?

CCCLXXXI. The nervous liquor then, which is the inſtrument of ſenſe and motion, muſt be exceedingly moveable, ſo as to carry the impreſſions of ſenſe, or commands of the will, to the places of their deſtination, without any remarkable delay: nor can it receive its motions only from the heart. Moreover, it is very thin and inviſible, and deſtitute of all taſte and ſmell; yet reparable from the aliments. It is carefully to be diſtinguiſhed from that viſible, viſcid liquor exhaling from the veſſels in the intervals between the nervous cords.

CCCLXXXII. That this liquor moves through tubes rather

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of the nerves proves, that ſuch a fluid under the name, and ſenſe, which determines fluids in our bodies, moving in canals and hollow fiſtulæ, does not exiſt. However, it is therefore not improbable, that that ſubſtance, which produces the wonderful phenomena in the nerve, is one of the claſs of the more ſubtile fluids of nature. I pretend not to give it a name. Since 1766, I have been inclined to think, that it perhaps reſembles the electric and magnetical fluids; ſince which time, long before Miſmer, I publicly taught the power of magnetiſm upon our body. For this reaſon the nervous principle has been in note 67 numbered in the third claſs of fluids. We may expect that this obſcurity will be greatly removed by the very celebrated anatomiſts Drs Monro and Prochaſka, who have extended and directed their ſtudy to the phyſiology of the nerves.

rather than through a ſpongy ſolid, we are perſuaded from its celerity, and the analogy of the whole body; of which all the liquids, the fat excepted, run through their proper veſſels.

CCCLXXXIII. Therefore, upon the whole, it ſeems to be certain, that, from the veſſels of the cortex, a liquor is ſeparated into the hollow pipies of the medulla, which are continued with the ſmall tubes of the nerves, even to their ſoft pulpy extremities, ſo as to be the cauſe both of ſenſe and motion. But there will be a twofold motion in that humour; the one ſlow and conſtant, from the heart; the other not continual, but exceedingly ſwift, which is excited either by ſenſe or any other cauſe of motion ariſing in the brain.

CCCLXXXIV. The ſame nerves moſt evidently preſide over both ſenſe and motion; as we cannot admit a diſtinction between the two ſyſtems of motory and ſenſitive nerves. If ſenſe ſometimes remains after motion is deſtroyed, this ſeems to be becauſe much more ſtrength is required for the latter. Dying people hear and ſee, when they are incapable of motion.

CCCLXXXV. If it be aſked, What becomes of this nervous juice, which cannot but be ſeparated and diſtributed in great abundance, from ſo large a quantity of blood paſſing the brain very ſwiſtly, in compariſon of the ſlower moving blood, from whence the milk is ſeparated in the breaſt, and the urine in the leſſer renal artery, or by a compariſon with the meſenteric artery? it may be anſwered, It exhales probably through the cutaneous nerves; the laſſitude both with reſpect to ſenſe and motion, which may be overcome by ſpirituous medicines, ſhows that this liquid may be both loſt and repaired. Many have judged, that it alſo exhales into the various cavities of the body; as that of the ſtomach and inteſtines. We may expect ſome part of it to be reſorbed, that the nobleſt humour of the body may not be too quickly diſſipated. That it nouriſhes the body, is incredible: It is too moveable to expect adheſion from it: that is the office of a ſlow and viſcid humour.

CCCLXXXVI. But then, what is the deſign of ſo many protuberances in the brain? what are the particular uſes of the ventricles, nates, and teſtes; with the diſtinction of the brain from the cerebellum; and the communication betwixt one ſide of the brain, cerebellum, and ſpinal medulla, with their oppoſite ſides, by ſo many tranſverſe bundles of fibres [106]?

CCCLXXXVII. The ventricles ſeem to be made of neceſſary conſequence, and towards the greater uſe and diſtinction of the parts. And that the corpora ſtriata or thalami might keep their medullary parts from cohering one to another, it was neceſſary for a vapour to be poured betwixt them; and the ſame is true with regard to the brain and cerebellum. Perhaps, likewiſe, the neceſſity of adminiſtring a degree of warmth to the cloſe medulla of the brain, may be one reaſon for theſe cavities, by which the arteries enter, and are diſtributed in great numbers. Perhaps alſo it was proper, that, in the inmoſt parts of the brain, ſmall veſſels only, without any large ones, ſhould enter. We may alſo ſuſpect, that the ſoftneſs of the fibres of the brain requires ſhortneſs in order to ſuſtain their own weight.

CCCLXXXVIII. The uſes of moſt of the protuberances we are not acqainted with, but have them yet to learn from diſeaſes, and from anatomical experiments made on animals having a brain like that of mankind. But, in theſe reſpects, we have little hopes of ſucceſs, in parts that are ſo ſmall, ſo deeply, and ſo difficultly ſituated, and hardly ever to be approached but by a wound ſoon fatal. Whether theſe parts are ſo many diſtinct provinces in which our ideas are ſtored up, and whether this be confirmed by the protuberant thalami of the optic nerve, are indeed queſtions. But then moſt of theſe protuberances ſend out no nerves at all.

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[106] Theſe queſtions will be anſwered, when the brains of ſeveral animals ſhall have been compared with their functions. The learned Sommering has already ſaid much about this ſubject, and Camper likewiſe in fiſhes.

CCCLXXXIX. As to the internal communication of one part with the other by ſtriæ or ducts; that ſeems to conduce to the advantage of motion, and probably of ſenſe likewiſe. Some of theſe communications join the brain with the cerebellum; others join the ſpinal medulla with the nerves of the brain itſelf, as in the acceſſory nerve; and moſt of them join the right and left parts together, as in the anterior commiſſure (CCCXLV.), and in the two poſterior (CCCL.), in that of the corpus calloſum (CCCXLIII.), in the ſtriæ betwixt a proceſs of the cerebellum and teſtes (CCCLIV.); to which add the medullary croſs-bars in the medulla oblongata and ſpinalis (CCCLV.) For from this ſtructure, it ſeems manifeſtly to follow, as well as from numberleſs experiments and obſervations, that when the right ſide of the brain is injured, all the nerves which, on the contrary, belong to the left ſide of the body, become diſeaſed or paralytic, and the reverſe. Moreover, by this contrivance, nature ſeems to have provided, that, in whatever part of the brain any injury may happen, the nerve that ariſes from thence is, by this means, not always deprived of its uſe. For if the ſaid nerve receives its fibres by communicating bundles, as well from the oppoſite as from its own hemiſphere of the brain, its office may in ſome meaſure be continued entire by the fibres which it receives from the oppoſite ſide, even after thoſe of its own ſide are deſtroyed. Accordingly we have numberleſs inſtances of wounds, and with a conſiderable loſs of ſuſtance from the brain, which yet have not been followed with injury to any nerve, or to any of the mental faculties. Many other leſs inequalities, ſtripes, protuberances, and nerve-like impreſſions, appear in the brain from mechanical neceſſity, with the pulſation of the veſſels, and the preſſure or figure of the continuous incumbent parts.

CCCXC. We have before declared, that the nerves are the organs of ſenſe and motion: we ſhall therefore proceed firſt to explain that motion before we deſcribe the organs of ſenſe; becauſe it is more ſimple, uniform, and perpetually exerciſed, even in the fœtus, before any of the ſenſes.

CHAP. XII.

Of MUSCULAR MOTION.

CCCXCI. MOTION in the human body is not performed by one individual organ. In every animal and vegetable fibre, alſo in hair, feathers, membranes, the cellular texture, and in the humid muſcular fibre; in ſhort, in animal and vegetable gluten; there is a contractile power, which both reſiſts the lengthening out of its ſubſtance, and, when the extending power is taken away, reſtores the fibre to its former ſize; nor does this power ever ceaſe endeavouring to bring the elementary particles into the cloſeſt contact the mechaniſm of the part can admit. After death, even for many days, it does the ſame; ſo that fibres of a divided muſcle contract towards each extremity, leaving a wide gap in the middle. An artery, when cut, likewiſe contracts itſelf in length.

CCCXCII. I call this force *dead*, becauſe it continues to be efficacious after death, and ſo is different from the powers of life. In the living animal indeed it is ſomewhat briſker: for, both from cold and fear, the ſkin is moved, ſo that it grows harder, and has its papillæ erected, and along with this hardneſs contracts itſelf in length. Again, the cellular fibres are animated with this perpetual niſus to ſhorten themſelves, and always tend to their own contraction. Hence, when the ſkin or any other membrane is extended, as ſoon as the cauſe of extenſion is taken off, it returns by a gentle effort to its former ſhortneſs. But it even ſomewhat reſiſts the attempt to perpetual diſtenſion; and by a gentle but continual acceſſion of its own elements, propels the contained fat or water, or other bodies accidentally introduced. The ſame power alſo ſeems to limit the excretion of vapour; for the fibres and plates of the cellular texture being preternaturally relaxed, an immenſe quantity either of fat or of watery humour is depoſited in that texture. And this debility ſeems to be the principal cauſe of a true dropſy. The ſame cauſe being always efficacious, and at work in the heart, joints, and every where throughout the body of the embryo, brings into nearer contact the arteries, auricles, and ventricles; produces flexures; and contracts the heart, when in a manner diſſolved into a cone. The ſame, by an unknown or hidden power, ſeems to form the ſhape of moſt parts of the human body; and while it expels the gluten received into the cells, brings the terreſtrial particles nearer to one another, and gives the proper ſolidity, curvature, and ſituation, to the different parts.

CCCXCIII. It is the nature of this power to act continually by a gentle but uninterrupted effort. It is common for it alſo to be excited by poiſons, in every membrane, fibre, and cellular texture; but never by cutting or puncturing with an iron inſtrument. Theſe are the known properties of the red muſcular fibre. The ſtructure of this fibre, then, it is now neceſſary for us to conſider.

CCCXCIV. By the name of *muſcular fibres* in the human body, we call bundles of reddiſh-coloured threads, which perform all the motions of which we are ſenſible. When many of theſe fibres are collected together, and appear more evidently red, they are called *a muſcle.* The extreme ſimplicity of the fabric in theſe parts has been the cauſe of the obſcurity that prevails in underſtanding how a ſmall, ſoft, fleſhy portion, can produce ſuch ſtrong and ample motions as we ſee in man, but more eſpecially in the cruſtaceous inſects.

CCCXCV. In every muſcle we meet with long ſoft threads or *fibres*, ſomewhat elaſtic or extenſible, and almoſt conſtantly diſpoſed parallel with each other; and theſe, being ſurrounded with a good deal of cellular ſubſtance, are by that faſtened together into little bundles.

dles. Thoſe bundles, called *lacertuli*, are again tied together into larger bundles, by a more looſe cellular network, which contains ſome fat; and betwixt theſe we conſtantly perceive membranous partitions and ſtripes of the cellular ſubſtance removing them farther from each other, till at laſt a number of them combined together in a poſture either parallel or inclined[107], are ſurrounded with a more thin and denſe cellular membrane, continuous with that of their partitions; and this being again ſurrounded by a thicker plate of the cellular ſubſtance, externally parts the whole from the adjacent fleſh, and gives it the denomination of a *ſingle* or *entire muſcle*. In every one of theſe threads there appears a leſſer ſeries of filaments, which, by oblique extremities, are cemented to others of the ſame kind, forming together a larger fibre.

CCCXCVI. The generality of the muſcles, but more eſpecially thoſe which are inſerted into the bones, and ſuch as are preſſed ſtrongly by other fleſhy incumbent parts, do not conſiſt of fibres altogether of one kind. For the fleſhy fibres (CCCXCV.) being collected together, cauſe the muſcle to be thicker in the middle, which is called its *belly:* and the ſame fibres degenerating by degrees obliquely at each end of the muſcle into a more ſlender, hard, and ſhining ſubſtance of a ſilver colour, in which meeting cloſer together, the cellular ſubſtance interpoſed is thinner, ſhorter, and painted with fewer veſſels; they then become indolent and difficultly irritable, and receive the denomination of a *tendon*, by being collected together into a round ſlender bundle; or elſe, if it expands into a broad flat ſurface, it is called an *aponeuroſis*. The cellular texture which covers the whole tendon is called its *vagina* or ſheath, and reſembles the coat of a muſcle. For that the fleſhy fibres truly change into ſuch as are tendinous, is evident from comparing a fœtus (in which there are very few

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[107] Swammerdam, Lyonet and Roeſel, have elegantly painted this ſtructure in frogs and palmers, which Leewenhoeck, Cowper, Muyſs, and Proſchaſka have ſhown in man.

few tendons) with a child of ſome years growth, in which there are many more; and both with an adult or old perſon, in which are the greateſt number[108]. Muſcles, which are not inſerted into any of the bones, have commonly no tendons, as the ſphincters and muſcular membranes of the viſcera and veſſels. But thoſe commonly end in long tendons, which are required to paſs round the joints and heads of the bones, to be inſerted in thoſe extremities which are more moveable. In a fœtus the muſcles are evidently inſerted into the periosteum only; but in adults, where the perioſteum is more cloſely joined with the bone itſelf, the tendons, being confuſed with the perioſteum, paſs together with that even into the foveoli of the bone.

CCCXCVII. The tendinous fibres indeed often lie in a ſtraight line with the fleſhy ones, and are as it were a continuation of them. But it is not at all rare for the fleſhy fibres to be obliquely inclined to the tendon, and to adhere to it, as the tendon itſelf grows thicker in its progreſs by continually receiving new fibres. This is called *a tendinous muſcle*. Other tendons lie in the middle betwixt two plates of fibres, forming an obtuſe angle with one another, at irregular diſtances, in their deſcent. There are inſtances of numerous tendons pennated in different places formed into one muſcle. There are alſo other methods by which the tendinous fibres are joined with the fleſhy ones.

CCCXCVIII. Within the cellular tunic, that ſurrounds the fibres, the arteries and veins are ſubdivided into networks, which commonly form right angles, run in company, and moſtly contiguous with each other; and from the ſmaller of theſe veſſels a vapour is exhaled into the thinner cellular ſubſtance, as the fat is alſo transfuſed into the thicker cellular ſubſtance; from whence again they are both abſorbed. The lympthatic veſſels, which run be-

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[108] Many tendons are found in a fœtus, which could not aſſume this nature by muſcular action; as the tendo-Achillis, aponeuroſis plantaris, centrum diaphragmatis, &c. Read the like opinion in Moſcate, *Atti di Siena*, Vol. IV.

betwixt the muſcles of the tongue, with thoſe of the neck, face, and limbs, are difficultly demonſtrated[109]. But there are alſo nerves more numerous than in other parts, diſtributed together with the blood-veſſels throughout the cellular fabric of the muſcle; which nerves, however, depoſite their harder covering, and become ſoft, and diſappear before they can be traced to their ultimate extremities. Thoſe enter the muſcle in many parts, without keeping to the ſame place or ſituation. In the tendons they cannot be demonſtrated. Nor are there any nervous fibres inveſting the muſcular bundles or portions, ſo as to conſtringe them; for they, who have given ſuch a deſcription, have ſeen nothing but the cellular ſubſtance.

CCCXCIX. The fabric of the leaſt fibre, which is as the element of a muſcle, being inveſtigated by the microſcope in man and other animals, has always appeared ſimilar to the fabric of the larger fibres; nor do they yield any other appearance, upon which we can rely, than that of the leaſt threads joined one to the other by the intermediate cellular ſubſtance. There is, therefore, no foundation here for a ſeries of veſicles, nor for a chain of rhombs. It may be aſked, whether theſe fibres are hollow, whether they are continued with the ar-

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[109] The lymphatic veſſels, even of the joints, are now to be reckoned among the conſtant veſſels. I have obſerved a broad net-work running from the carpus and palm of the hand, in the inſide of the arm, in the duct of the veins following the radius and ulna, towards the bend of the fore-arm, in two trunks, joined by various intermediate rami; into which net-work run ſome branches from the outſide of the cubit and arm: they run in a manifold net-work upon the bend of the fore-arm and inſide of the humerus, till by two or three trunks they arrive at the axillary glands, and mix with the ſubclavian plexus. In the inferior extremity, I could render viſible ſeveral of theſe lymphatic veſſels, in three or four trunks upon the leg, and one on the inſide of the foot, going to the ham; then in a few trunks, the number various, they run up from the net-work of the ham, around the inſide of the thigh, in the duct of the vena ſaphena, and are loſt in the inguinal plexus and glands there ſituated; and at laſt a greater plexus enters the abdomen along with the crural veſſels. The ſame veſſels have been ſeen by Hewſon almoſt in a ſimilar diſpoſition.

arteries, or whether the difference betwixt muſcular and tendinous fibres lies in the latter being rendered more denſe and beat cloſer together by an expulſion of the fluids? That theſe are not probable, appears from the minuteneſs of the fibres, which are found leſs than the red-blood globules, and from the whiteneſs of a muſcle after the blood is waſhed out of it; to which add the phyſiological reaſons following, (CCCCXI.) And, in general, more ſtrength may be expected from a ſolid fibre.

CCCC. A muſcle therefore is endowed at leaſt with a threefold force[110]. Firſt, the dead one, in common to it with other animal fibres. Another, which we have called the *vis inſita*, and which has different phenomena from the former. For it is more proper to life, and the firſt hours after death, and diſappears much ſooner than the dead one. Again, in moſt caſes, it acts by alternate oſcillations; ſo that, being driven hither and thither, it ſometimes contracts the muſcle towards the middle: ſometimes again it extends the muſcle from the middle towards the extremities, and ſometimes alſo it has a reiterated motion. Moreover, it is manifeſtly quicker, and performs the greateſt motions; the dead force, only ſuch as are ſmall and not eaſily obſerved. It is excited both by the pricking of an iron inſtrument, and in the hollow muſcles by inflated air, by water, and every kind of acrimony, but moſt powerfully of all by a torrent of electrical matter. Laſtly, it is proper to the muſ-

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[110] Theſe three noted claſſes of animal powers, elaſticity, irritability, and ſenſibility, have been and are yet too much confounded, although it is no difficult taſk to diſtinguiſh theſe affections of the fibres from one another. The force and nature of elaſticity, poſſeſſed by the fibres, which, only in different degrees, pervades all parts without exception, was fully known to Bellini, Baglivi, Stahl, Pacchioni, Jancker, &c. This power, known to Stahl's followers under the appellation of *tone*, has no ſimilarity to irritability, ſenſibility, and vital power, ſo called: it does, however, either alone perform the actions of the animal and vegetable body, or adds ſtrength and vigour to them; the former is manifeſt in the motion of the ribs and cartilages, and the latter in the conſtriction of the uterus, veſſels, and membranes. It by no means obeys the laws of life alone, but may endure long after death; it is not deſtroyed completely but by putrefaction alone. During life it is diminiſhed by various cauſes, and again reſtored by ſeveral remedies. Irritability, which Haller thought exiſted in the fibres of the muſcles alone, in name indeed but not in reality, and which was known to Gliſſon, is a new genus of animal power; nor does the word ενορμουν of Hippocrates, ſignify the ſame thing. It is almoſt proved, from the experiment of Lups, Haller, Fontana, Hoffman, and ſeveral others, that it is different from elaſticity in its riſe, duration, ſeat, cauſes, effect, and phenomena. I ſhall add a few remarks: 1. It is moſt powerful in the muſcular fibres of the whole body, but not equally diſperſed through all; more powerful in the heart, muſcles of reſpiration, and inteſtines; becomes gradually weaker among the voluntary muſcles, and perhaps, in a trivial degree, in the veſſels, membranes; but always ſome however exiſts, as appears from the doubts offered by Whyte, De Haen, Van Doeveren, &c. to which Haller in part, and alſo the learned Cigna, have anſwered. 2. The phenomena of irritability and the irritation, themſelves, by which thoſe are produced, are, not always the ſame: For in ſome it advances in a regular tract, that

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that almoſt from any irritation you will always obſerve a manifeſt irritability: this is almoſt the caſe in all the muſcles. In many other parts you ſee the greateſt inconſtancy and a very irregular effect, as it will be one thing one day, another thing another day, now increaſed, now diminiſhed, one time yield to, another time reſiſt, the irritation: all which is evident in the ſkin, viſcera, veſſels, and iris. 3. The learned pathologiſts Eller, Tiſſot, Gerhard, have long ago acknowledged the very great riſe of the doctrine of irritability. It would be of much importance to know well the remedies, whether they be medicines, or remedies from diet or otherwiſe, which particularly conduce to excite irritability if it is languid, or to diminiſh it if it is too great. Opium, and the other narcotics, camphor, Spaniſh flies, acrid poiſons, bark, the electric ſhock, ſhow a clear influx of animal ſpirits in the production of irritability. 4. That it is different from the faculty of feeling, and therefore by no means to depend upon the nerves, appears partly from other reaſons, partly from the irritability of vegetables. Though I even wiſh to take into account ſome phenomena of the dionæa muſcipula, according to Ellis's obſervations, or of the ſenſitive plant or certain antheræ, I would be averſe to compare this contractile power of ſome parts of vegetables with irritability; for what makes the particular character of irritability, the internal tremor of the conſtituent parts, is wanting in all vegetables; we ſee contraction and motion alone, which are alſo obſervable in other elaſtic bodies, where we ſuppoſe no irritability to exiſt. The power of the nerves over irritability, the direction of the ſoul over muſcular motion, although they render it very probable, I, however, refer it to irritations alone. The faculty of feel-muſcular fibre, and is found in no other part of the human body with the qualities abovementioned. But we muſt give a more particular explication of its phenomena.

CCCCI. It is natural to every muſcle to ſhorten itſelf, by drawing the extremities towards its belly or middle. But to diſcover the moving power of a muſcle from the fabric which we have deſcribed, it will be of uſe to conſider the appearances obſervable in the muſcular contraction. Every muſcle then becomes ſhorter and broader in its action. But this contraction of its length is various; in ſome more, in others leſs; and is very conſiderable, for example, in ſome of the ſphincters, inſomuch that they appear to be contracted more than one third of their extent, though this computation be taken from an erroneous hypotheſis.

CCCCII. The inteſtines are exceedingly tenacious of their vis inſita, as they continue to contract themſelves long after they are taken out of the body, and even after they are cold. The heart is even more tenacious than theſe, if you conſider all things; as is moſt evident in a young chicken, and in cold animals. Different muſ-

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feeling, depending ſolely upon the nerves, although it has been regarded as one and the ſame thing with irritability, has been more ſtrongly oppoſed by Haller's opponents, De Haen, Whyte, Le Cat, Gerhard, &c. than irritability itſelf. But that ſenſibility of parts is to be referred both to the various quantity of the nerves, their ſituation and condition, according to Haller's and Caſtell's experiments, and to the various violence of irritation and nature of the irritating or offending body, ſo that they may be at times more or leſs painful; and at others, as Haller thinks, they may be altogether inſenſible. I ſhall not repeat what has often been objected to, that a greater pain having preceded, abſorbs a leſs pain following; as we do not feel the taſte of a drop of wine if we have taken a very ſmall quantity of rectified alcohol upon the tongue a little before. It cannot however be denied, that in inflammatory diſeaſes, affections of the mind, and other cauſes, it may happen, that hurt parts may now feel, which, under any other condition, may ſeem to be inſenſible. The *vital power* of certain learned men of later times, as Vanden Bos, Bikker, Gaubius, Albinus, &c. rather ſeems compounded of all the animal powers comprehended together; which opinion, except in ſome minutiæ, the great Boerhaave and Simpſon have more exactly adapted.

muſcles are beſt excited into action by different ſtimuli; as the bladder by urine, the heart by the blood, and the inteſtines by air. Though the nerves are removed, or the connection, made by them between the muſcles and the brain, cut off, the muſcles loſe but little of their irritable nature. It appears alſo from the example of polypi and other inſects, that the ſame irritable diſpoſition extends very widely through the animal fibres. Theſe creatures have neither brain nor nerves, yet are exceedingly impatient of ſtimulus. Laſtly, we may gather this from the affinity of plants: of which very many flowers and leaves open or contract according to the various degrees of heat and cold, ſome even very quickly: ſo that they are nothing inferior in this reſpect to animals. Neither does this depend upon weight, attraction, or elaſticity, ſeeing it is ſeated in a ſoft fibre, and vaniſhes when the ſame grows hard.

CCCCIII. But that the cauſe of motion is conveyed through the nerves into the muſcles, is certain from the experiments before mentioned (CCCLXVII. et ſeq.) For the nerve alone has feeling; this alone carries the commands of the ſoul; and of theſe commands there is neither intimation nor perception in that part, whoſe nerve is either tied or cut, or which has no nerve. Moreover, on irritating the nerve or ſpinal marrow, even in a dead animal, the muſcle or muſcles which have nervous branches from thoſe parts are moſt vehemently convulſed. When the nerve of any muſcle is cut or tied, or the baſis of the ſpinal marrow compreſſed, or that part of the brain from whence the nerve has its origin, the muſcle becomes paralytic, and languiſhes, and cannot by any force be recalled into action ſimilar to the vital one. But if the ligature be taken off from the nerve, the force by which the muſcle is put into action is again recovered by it. The nerve being irritated below the place where it is cut, the muſcle to which that nerve goes is contracted. This appears from numerous experiments, eſpecially thoſe made on the phrenic and recurrent nerves.

CCCCIV. This force is not the ſame with the vis inſita. The former comes to the muſcle from without; whereas the other reſides conſtantly in the muſcle itſelf. The nervous power ceaſes when life is deſtroyed; after which the other, from certain experiments, appears to remain a long time: it is alſo ſuppreſſed by tying a ligature upon the nerve, by hurting the brain, or by drinking opium. The *vis inſita* ſuffers nothing from all theſe: it remains after the nerve is tied; and continues in the inteſtines though taken out of the body, and cut in pieces: it appears with great ſtrength in ſuch animals as are deſtitute of brain: that part of the body is moved which has no feeling; and the parts of the body feel which are without motion. The will excites and removes the nervous power, but has no power over the *vis inſita*.

CCCCV. In the motion of the muſcles, whether owing to the *vis inſita* or the nervous power, the fibres are contracted towards the middle of their belly, and recede from one another outwards: they are alſo diverſified with various tranſverſe wrinkles: the whole muſcle alſo becomes ſhorter, and draws its extremities towards the middle; hence it draws towards each other thoſe parts with which it was connected, in the reciprocal ratio of their ſtrength: the muſcle alſo ſwells by its contraction, becoming hard at the ſame time, and as it were increaſes its circumference on every ſide. I have never obſerved it to turn pale. Whether on the whole it is increaſed in bulk, or acquires more in breadth than it loſes in length, is difficult to be known. It draws after it the tendons, which are obſequious to its motions, though of themſelves neither moveable nor irritable. The whole muſcle is alſo capable of being moved at once, or only a part of it: if one extremity is fixed to an immoveable part, that only is moved which is capable of yielding.

CCCCVI. If it be demanded, Whether the arteries conduce any thing to muſcular motion? and whether the palſy, which falls upon the lower limbs after a ligature upon the aorta, be not an argument thereof? we anſwer, Not at all, further than as they conduce to the integrity of a muſcle, or to the conſervation of the mutual ſtructure and habit of the parts, which they ſupply with vapour, fat, &c.: for the irritation of an artery does not affect or convulſe the muſcle to which it belongs; nor does a ligature thereof cauſe a palſy, unleſs after a conſiderable time, when the muſcles begin to be deſtroyed by a gangrene. Moreover, it is impracticable to explain the motion of peculiar muſcles from a cauſe derived with an equal force from the heart to all parts of the body. Laſtly, the influence of the will is confined to the nerves, without reſiding in the arteries or other ſolid parts of the body.

CCCCVII. But the direct manner by which the nerves excite motion in the muſcles, is ſo obſcure, that we may almoſt for ever deſpair of its diſcovery. And firſt, concerning the vis inſita, we do not indeed inquire; as this ſeems to be a more briſk attraction of the elementary parts of the fibre by which they mutually approach each other, and produce as it were little knots in the middle of the fibre. A ſtimulus excites and augments this attractive force, which is placed in the very nature of the moving fibre. The other explanations are hypotheſes. As to nervous veſicles ſwelling by a quicker flux of the nervous ſpirits, they are inconſiſtent with anatomical truth, which demonſtrates the leaſt viſible fibres to be cylindrical, and in no part veſicular; and likewiſe repugnant to the celerity with which muſcular motion is performed, and with the bulk of a muſcle being rather diminiſhed than increaſed during its action. Again, the inflation of rhomboidal chains in the fibres is equally repugnant to the celerity, to inſpection, and to anatomy; they would alſo occaſion an immenſe waſte of ſtrength, and after all render the muſcle but little ſhorter. The nerves want that irritable nature which is obſerved in the muſcular fibre. Finally, it is by no means demonſtrable, that the fibres, from ſo few nerves, can be ſo numerous, or diſtributed in ſo many different tranſverſe directions, with reſpect to the muſcular threads, as thoſe hypotheſes require to be allowed. A complication of the nerves round the extremities of fibres, ſo as to contract them by their elaſticity, is founded upon a falſe ſtructure of the muſcular fibre, ſuppoſing the nerves to be diſtributed, where filaments of the cellular ſubſtance only can be demonſtrated. Moreover, the phenomena of animals, which, having neither brain nor nerves, are yet very apt for motion, apparently demonſtrate the intrinſic fabric of the muſcles to be ſufficient for their motion, without other aſſiſtance from the nerves. Other explanations, derived from ſpherules full of air in the blood, ſuppoſe a falſe nature of that fluid; namely, a repletion of it with elaſtic air, of which it has none, (CCLXXXI.) The animal ſpirits are not of the nature of an electric torrent.

CCCCVIII. If we may add any thing to theſe phenomena, you may ſuppoſe the nervous liquor to be of a ſtimulating nature, by which means it forces the elementary particles of the muſcular fibre to approach nearer to each other. The motive cauſe which occaſions the influx of the animal ſpirits into the muſcle ſo as to excite it into action, ſeems not to be the ſoul, but a law derived immediately from God. For animals newly born, or newly transformed, without any attempt, or exerciſe, know how to execute compound motions, very difficultly to be defined by calculation. But the ſoul learns thoſe things which it does, very ſlowly, imperfectly, and by making experiments. That muſcle then is contracted which in a given time receives more of the nervous fluid, whether that be occaſioned by the will, or by ſome irritating cauſe ariſing in the brain, or applied to the nerve.

CCCCIX. But, though you may conjecture the ſoul to be the cauſe of the nervous motion, you cannot do the ſame with regard to that ariſing from the vis inſita. The heart and inteſtines, alſo the organs of generation, are governed by a vis inſita, and by ſtimuli. Theſe powers do not ariſe from the will; nor are they leſſened, or excited, or ſuppreſſed, or changed by the ſame. No cuſtom nor art can make theſe organs ſubject to the will, which have their motions from a vis inſita: nor can it be brought about, that they ſhould obey the commands of the ſoul, like attendants on voluntary motion. It is ſo certain that motion is produced by the body alone, that we cannot even ſuſpect any motion to ariſe from a ſpiritual cauſe, beſides that which we ſee is occaſioned by the will; and, even in that motion which is occaſioned by the will, a ſtimulus will occaſion the greateſt exertions, when the mind is very unwilling.

CCCCX. There ſeems to be this difference between the muſcles obeying the will, and thoſe which are governed by a vis inſita; namely, that the latter, being more irritable, are very eaſily excited into motion by a gentle ſtimulus; as for inſtance, the heart and inteſtines; which organs are moſt manifeſtly, and greatly, and conſtantly, irritable. On the other hand, the muſcles which obey the will, are neither endowed with ſo great nor ſo durable a power of this kind. Hence, they either ſtand in need of the power of the will, or a ſtronger ſtimulus; by which, indeed, when they are excited, even theſe are animated to motion againſt the will. Thus it happens, that, in apoplexies, the muſcles which obey the will languiſh, and become paralytic, as being deſtitute of all influx from the brain; while the vital muſcles, having no occaſion for the operation of the brain, continue to be excited into contraction by their ſtimuli, the heart by the blood, and the inteſtines by the air and aliments.

CCCCXI. The ſtrength of this action in the muſcles is very conſiderable in all perſons, but more eſpecially in thoſe who are phrenetic, and ſome who are called ſtrong men; ſince frequently, with the uſe of a few muſcles only, they will raiſe a weight equal to, or much greater than, that of the whole human body itſelf. For even in one who is in his ſenſes, very ſlender muſcles ſuffice to elevate 200 or 300 pounds. The muſcles of the back will even ſuſtain 3000. Notwithſtanding this, we ſee, that much the greater part of the force or power exerted by a muſcle is always loſt without producing any viſible effect. For all the muſcles are inſerted nearer the point or centre of motion, than the weights they are applied to; and therefore their action is weaker, in the ſame proportion as they move a ſhorter part of the lever than that to which the weight is applied. Moreover, in moſt of the bones, eſpecially thoſe of the limbs, the muſcles are inſerted at very acute angles; whence again the effect which a muſcle exerts in action, is proportionably leſs as the ſine of the angle intercepted betwixt the bone and the muſcle is leſs than the whole ſine. Again, the middle part of all muſcular force is loſt, becauſe it may be reckoned as a cord extended, and drawing an oppoſite weight to its fixed point. Again, many of the muſcles are ſeated in the angle of two bones, from one of which ariſing they move the other; and therefore, that bone being moved, they are bent, and of courſe, like an inflected cord, require a new force to extend them. Many of them paſs over certain joints, each of which they bend in ſome degree, whereby a leſs part of their remaining force goes to bend the joint to which they are particularly deſtined. The fleſhy fibres themſelves of the muſcles frequently intercept angles with the tendon in which they terminate; from whence a great part of their force is loſt, as much as is equal to the difference or deviation betwixt the ſine of the angle of their inſertion and the whole ſine. Finally, the muſcles move their oppoſed weights with the greateſt velocity and expedition, ſo as not only to overcome the equilibrium, but likewiſe to add a conſiderable celerity to the weight.

CCCCXII. All theſe loſſes of power being computed, make it evident, that the force exerted by muſcles in their contraction, is exceeding great beyond any mechanical ratio or proportion whatever; ſince the effect is ſcarce one-ſixtieth of the whole force exerted by the muſcle, and yet only a ſmall number of theſe muſcles, weighing but a few pounds, are able not only to raiſe ſome thouſands of pounds, but alſo with a conſiderable celerity. Nor is this to be reputed any defect of wiſdom in the Creator: For all thoſe loſſes of power were neceſſary towards a juſt ſymmetry or proportion of the parts, with the various motions and celerities required by the muſcles to act in different directions; all which circumſtances bear a relation to the mechaniſm of compound engines. But we may, however, conclude from hence, that the action of the nervous or animal fluid is very powerful, ſince, in an engine ſo ſmall, it can exert a force equal to ſome thouſand pounds for a conſiderable time, or even for many days together; nor does this ſeem to be otherwiſe explicable, than by the incredible celerity by which the influx of this fluid obeys the command of the will. But how, or whence it acquires ſuch a velocity, is not in our power to ſay; it is ſufficient, that we know the laws of its motion are ſuch, that a given action of the will produces a new and determinate celerity in the nervous fluid.

CCCCXIII. The eaſy and ſudden relaxations of muſcles in their motion are aſſiſted by the actions of their *antagoniſt* muſcles. Namely, in all parts of the body every muſcle is counterpoiſed by ſome weight, elaſticity, an oppoſite muſcle, or a humour acting againſt the cavity of a muſcle, by which it is expelled. This cauſe, which is a vis inſita, continually operates as long as the muſcle acts; and ſo ſoon as the additional celerity derived from the brain abates, it reſtores the limb or other part immediately to its former eaſy ſtate, in which there is an equilibrium betwixt the muſcle and its oppoſing cauſe. Whenever the antagoniſt power is removed from the muſcle, there are none of them but muſt contract, extending their oppoſites, by which the diſtended nerves excite an uneaſy ſenſe, and cauſe a ſtronger endeavour towards recovering the equilibrium. Hence one of the flexor muſcles being cut in two, the extenſor operates even in a dead body; and the reverſe.

CCCCXIV. But there are other means, by which the motions of the muſcles are rendered more ſafe, certain and eaſy. The large long muſcles, by which the greater er motions of flexure are performed, being included in tendinous capſules or caſes, drawn and tightened by other muſcles, are thus ſecured and ſtrengthened; for ſo the muſcle remains preſſed againſt the bone, in a ſtate of contraction, all the time that the limb is bent, and avoids a conſiderable loſs of its power. But the long tendons, which are incurvated or extended over joints in their motion, are received and confined by peculiar bands, which retain them within their ſlippery channels, and keep them from ſlipping out under the ſkin; which diſlocation of the tendon, whenever it happens, is attended with a cramp of the muſcle, ſevere pain, and loſs of motion; and in theſe ſheaths a particular liquor is ſeparated for the lubricating of the tendons. The ſame kind of care we obſerve taken by nature in the caſe of muſcles which perforate others in their courſe. In other parts, the tendons are either carried round certain eminences of the bone, in order that they may be inſerted at greater angles into the bone which they move; or elſe they are inſerted into another bone, from whence a different tendon deſcends under a larger angle into the bone to be moved. In other parts, the muſcles which are derived from convenient ſituations, have their tendons carried round in a contrary direction by nature, ſo that they paſs into the part to be moved as it were round a pully. Nature has likewiſe ſurrounded the muſcles on all ſides with fat, which is ſpread alſo betwixt their bundles of fibres and the ſmall fibres themſelves which lie contiguous: which fat, being preſſed out by the turgeſcence of the muſcles and fibres, renders them ſoft, flexible, ſlippery, and fit for motion.

CCCCXVI. Moreover, the power and action of one muſcle is determined by the co-operations or oppoſitions of others, which ſerve either to hold firm ſome part from whence the muſcle ariſes, or to bend it together with the muſcle, or elſe to change its action from the perpendicular to the diagonal, by concurring to aſſiſt its force at the ſame time. The muſcles alſo aſſiſt one another, even thoſe which are ſeparated at a conſiderable diſtance, the firſt keeping the bone firm which is not to be moved, out of which the ſecond ariſe. Therefore, the action of no one muſcle can be underſtood from conſidering it alone; but all the others muſt likewiſe be brought into the conſideration, which are either inſerted into the muſcle itſelf, or into any of the parts to which the ſaid muſcle adheres.

CCCCXVII. By theſe muſcles, variouſly conſpiring and oppoſing each other, are performed walking, ſtanding, flexion, extenſion, deglutition, and all the other geſtures and offices of the ſeveral parts in the living body. But the muſcles have likewiſe ſome common or public actions, by which they are of uſe to the whole animal. They haſten the return of the venous blood, by preſſing it out both from the veins of the muſcles themſelves and from the veins which lie betwixt them; for the blood in theſe veſſels, diſtributed betwixt the turgid bundles of a contracted muſcle, is, by the valves, determined towards the heart only: they likewiſe return the fat to the blood; and ſhake, grind, or condenſe the arterial blood, and return it quicker to the lungs. Again, in the liver, meſentery, womb, &c. they promote the courſe of the contained blood, bile, and other juices, ſo as to leſſen the danger of their ſtagnation: they ſerve alſo to increaſe the ſtrength of the ſtomach, by adding their own ſtrength to it, whereby digeſtion is promoted; inſomuch that all ſedentary and inactive courſes of life are contrary to nature, and pave the way to diſeaſes from a ſtagnation of the humours, or from a corruption or crudity of the aliments. The large muſcles, which are generally placed round any of the cavities of the body, propel the blood contained in that cavity, and preſs it towards the heart. But by too much exerciſe or action, the muſcles themſelves grow hard and tendinous on all ſides; render the parts upon which they are incumbent cartilaginous, or elſe change thoſe which are membranous into a bony nature; increaſe the roughneſs, protuberances, and proceſſes, of the bones which lie next to them, and excavate their flat parts; dilate the cells ſeated in the diplöe, and bend the bones towards theſe parts.

CCCCXVIII. The muſcle which the ſtimulus has ceaſed to irritate, or for the action of which the mind has no occaſion, is relaxed, and grows ſoft; its wrinkles are filled up, and grow plain; its fibres are rendered longer, receding from the middle towards the fixed extremities; and its ſwelling falls. Whatever is the cauſe of additional contraction is then taken away; but that remains, without which the muſcle never is, as long as it is alive. Nor is this the work of an antagoniſt muſcle, although it may be aſſiſted by it. It may be aſked, What becomes of the ſpirit that is ſent forth from the brain? A part of it perhaps exhales; I ſuſpect a part to adhere to the fibre; and thus it happens, that the muſcles grow ſtrong with exerciſe, and their brawny parts become thicker.

CHAP. XIII.

Of the Senſe of TOUCH.

CCCCXIX. THE other office of the brain and nerves is to *feel;* that is, to ſuffer a change from the actions or impreſſions of external bodies, and thereby to excite other correſponding changes or repreſentations in the mind. We ſhall therefore firſt lead our examination to each of the ſenſes in particular [111];

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[111] It is a commonly received opinion that there are five ſenſes; becauſe ſo many different places of the body, which they call *organs of ſenſe*, are affected by a like number of bodies acting upon us. The ſkin is affected by the action of the bodies that touch it, the taſte by ſapid bodies, the noſtrils by odorous bodies, the ears by ſonorous bodies, and the eye by light. Does this diviſion and diſtinction of the ſenſes into five perfectly coincide with nature? Whoever will conſider, that the different tempers of the air, whether they depend on its changed elaſticity or upon its abundance or defect of electric matter, or upon the preſence of vapours, cold, or heat, produce in ſome, yea ſeveral animals and men, ſo manifeſt an effect, that ſome can thence preſage inſtant changes; whoever would conſider the wonderful effects of hunger and thirſt, and likewiſe duly attend

and then conſider what is common to all of them, with the changes which follow in the common ſenſory and in the mind.

CCCCXX. The ſenſe of touch is underſtood in a twofold manner. For, by this term in general, we call all changes of the nerves, ariſing from heat, cold, roughneſs, ſmoothneſs, weight, moiſture, dryneſs, or other affections of external bodies, in whatever part or organ they are applied to cauſe a change. In this ſenſe, the touch is aſcribed to almoſt all parts of the human body, to ſome more, to others leſs; as in different places of the body the nerves are more numerous and bare, or covered with more tender membranes; and thus even pain, pleaſure, hunger, thirſt, anguiſh, itching, and the other ſenſations, belong to the ſenſe of feeling.

CCCCXXI. But, in a ſomewhat different and more proper acceptation, the ſenſe of touch is ſaid to be the change ariſing in the mind from external bodies applied to the ſkin, more eſpecially at the ends of the fingers. For, by the fingers, we more accurately diſtinguiſh the qualities of tangible things than by other parts of our body.

CCCCXXII. Indeed, this ſenſe does not eaſily diſtinguiſh any particles by the ſkin which it does not touch. But ſince the touch is more peculiarly aſcribed to the cutaneous papillæ, therefore the ſtructure of the ſkin is to be firſt deſcribed. That part, then, which is called the *true ſkin*, is compoſed of a thick cellular net-work, whoſe fibres and plates are cloſely compacted and interwove together in an intricate manner, which renders it porous, and capable of contracting or dilating to a ſurpriſing degree. Its ſtrata, when expoſed to the air by turning up the epidermis, become more cloſely compacted together; the ſame is inſenſibly relaxed towards

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attend to the phenomena of the exquiſitely ſenſible parts which are deſtined for generation; he will truly find many arguments for increaſing the number of ſenſes. But if you reflect upon the diverſity of organs, and particularly the diſtribution of the nerves, you will perceive a natural difference in the ear alone and eye.

wards fat, and is reſolved into a ſofter cellular texture. It is more tender in ſome places, and in others more hard. Within this ſubſtance run many ſmall arteries, which come from the ſubcutaneous ones, which, tho' neither large nor of a very great length, are yet numerous in ſome parts of the ſkin, which look red, as in the cheeks; but in other parts they are fewer in number. The veins ariſe in great numbers from the ſubcutaneous net-work, and the nerves likewiſe in the ſkin are very numerous; but they vaniſh ſo ſuddenly, that it is very difficult to trace the ultimate extremities of them. Betwixt the ſkin and muſcles is placed the cellular fabric, into which the ſkin is inſenſibly reſolved, in moſt parts repleniſhed with fat, the little eminences of which preſs upon the ſmall hollows of the ſkin; but in ſome, as the penis, red part of the lips, &c. it is deſtitute of fat. There are very few parts in the body of man where the ſkin is immediately joined to the muſcular fibres without any ſeparation by fat or cellular ſubſtance; for, though the dartos of the teſticle has no muſcular fibres, it is not without the cellular ſubſtance. There are ſome places, indeed, where tendinous fibres are inſerted into the ſkin; as in the neck, in the palms of the hands, and ſoles of the feet.

CCCCXXIII. Throughout the whole ſurface of the ſkin in moſt parts of the body, but with ſome difficulty, you will find it to have a rough appearance after the cuticle is taken off; but in the human body theſe are ſo obtuſe, that, unleſs you underſtand them to be very minute granulations, they are raiſed hardly any viſible height above the ſkin. But in the ends of the fingers there are larger round papillæ ſeated in cavities of the cuticle[112], and receiving nerves very difficulty ſeen; namely, a little mount or protuberance formed of ſmall veſſels, with one or more ſmall nerves wrapped up together in the cellular ſubſtance. Theſe, in the lips and glans penis, after long maceration, appear villous or down-like; and are ſeen moſt evidently of all in the tongue, from the fabric of which we conclude, by analogy with reſpect to the other cutaneous papillæ.

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[112] The cutaneous papillæ, no regard being paid to their difference of ſituation, are all formed from the cellular texture, which ſerves them for a foundation, into which ſeveral furrows of veſſels are directed; and the filament of a nerve, which is eaſily found in the tubercles of the tongue and penis when it reaches this tubercle, is as if ſoftened and abſorbed into a ſponge. Albinus has elegantly repreſented the diverſity of the papillæ.

CCCCXXIV. Over the ſurface of the ſkin is placed another covering, which is not ſo liable to be injured by the air, and which coheres with the ſubjacent ſkin by an infinite number of ſmall bloodleſs veſſels, and by hairs which paſs through its ſubſtance. The outer ſurface of this covering, as it were of an horny fabric, is dry, inſenſible, and not ſubject to putrefaction; but being deſtitute of veſſels and nerves[113], it appears in a particular manner wrinkled and ſcaly, and is joined to the ſkin by a kind of net-work. This is called the *epidermis* or *cuticle*, which is perforated by an infinite number of pores, ſome larger for the ſweat, and others ſmaller for the perſpirable vapours; out of whoſe ducts, expanded and cemented by the interpoſition of a condenſed glue, the ſubſtance of the cuticle is probably compoſed. By preſſure or burning, the cuticle grows thicker, by the addition of new plates or ſcales, formed betwixt the ſkin and thoſe which lie outermoſt; and this is called *a callus*. But even naturally, in Blacks, the cuticle has two diſtinct plates.

CCCCXXV. The inner ſurface of the cuticle is more ſoft and like a pulp, ſomewhat like an half fluid or a concreted mucus; whence, by macerating ſome time in water, it ſeparates from the former, difficultly in Europeans, but eaſily in the Blacks, where it is truly membranaceous, ſolid, and ſeparable, as in the palate of brutes. This ſurface of the cuticle lies incumbent on the ſkin itſelf, whoſe papillæ, in thoſe parts where they are to be found, are received into the ſoft cuticular alveoli or ſockets. This is commonly called *rete Malpighianum*, although it be certain there are no perforations viſible through it like thoſe of a ſieve.

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[113] The nature of the epidermis, the manner of its regeneration, and the controverted aſſertion of the veſſels and nerves preſent in it, have been again propoſed by Malpighius, Boerhaave, and Albinus. Klinkoſch choſe to refer it to a cellular nature: but the great affinity of the epidermis with the hair, nails, and horn, ſufficiently declares its nature; in which neither my injections nor knife have yet been able to diſtinguiſh either veſſels or nerves.

CCCCXXVI. That this reticular body is compoſed of a humour tranſuding from the ſurface of the true ſkin, ſeems very probable. As to the fabric of the cuticle itſelf, it is obſcure; for ſince it is both caſt off, or regenerated, inſenſible, and deſtitute of veſſels, it does not ſeem to belong to the organical parts of the body. Whether is it the outer part of the Malpighian mucus (CCCCXXV.) coagulated and condenſed by the air and by preſſure, after being perforated with a number of exhaling and inhaling ducts, the mouths of which are cemented together by the interpoſed condenſed glue? and whether or not are we perſuaded to this opinion by the mucous expanſion upon the membrane of the tympanum? to which add, the diſſolution of it in water, obſerved by the more eminent anatomiſts; which experiment is by others denied in the cuticle of Blacks.

CCCCXXVII. Moreover, to the hiſtory of the ſkin belong the ſimple glandules, which are ſeated in very many places under the ſkin in the cellular fabric; from whence perforating the ſkin by their excretory duct, they pour out a ſoft half fluid liniment. Other ſebaceous glandules, partly ſimple and partly compound, generate a dry white liniment, of an harder conſiſtence in the face, but more oily in the groins and arm-pits, with which the ſkin being anointed, ſhines, and is defended both from the air and outward attrition. They are found ſeated in all parts of the body that are under a neceſſity of being more immediately expoſed to the air, as in the face, where there are a great number of the compound ſort; or wherever the ſkin is liable to any great attrition, as in the arm-pits, nipples, groins, glans penis, nymphæ, anus, and hams. They frequently ſend out hairs. If it be aſked, Whether theſe follicles are ſeated in all parts of the ſkin? we anſwer, That although anatomy does not every where demonſtrate them, yet it ſeems probable that they are in no part abſent, as may appear from the ſordes collected about the whole ſurface of the body, ſeemingly of the ſebaceous kind. But there is another ſort of liniment poured out upon the ſkin from the fat itſelf, by its particular pores, without the intervention of glands (CCIX.); and this more eſpecially where the ſkin is clothed with hair, as in the ſcalp.

CCCCXXVIII. Again, both the hair and nails are appendages to the ſkin[114]. The former are ſcattered over almoſt the whole ſurface of the body, the palms of the hands and ſoles of the feet excepted; in moſt parts ſhort and ſoft; but longer upon the head, mouth, cheeks, and chin, with the breaſt in men; alſo, upon the fore part of the limbs, in the arm-pits, groins, and pubes. They ariſe from the cellular texture lying under the ſkin, originating from a little bulb which is membranous, ſtrong, vaſcular, and of an oval ſhape, and more lax towards the cellular texture, (and from this baſis the hairs are augmented by veſſels); in which little bulb another bulb lies hid, at firſt roundiſh, but afterwards cylindrical, and ſurrounded with blood. In that ſecond bulb lies the hair, laid over with a fat humour. The hair, with both its cylindrical ſheaths, comes to the cutaneous hole, goes out through the ſame paſſage, and forces the epidermis into a ſimilar ſheath; from whence the incorruptibility of the hair: and then the cover cannot be ſeparated farther from the cortex; but the filaments, and ſpongy and cellular matter, are continued throughout the whole length of the hair. The hairs grow naturally in the cellular ſubſtance under the ſkin; but, by diſeaſe, they are ſometimes formed within the fat of other parts. They grow continually; and are renewed again, after being cut, by a protruſion of their medullary ſubſtance from the ſkin outward, under a production of the cuticle. When the hairs are deſtitute of this medulla in old people, they dry up, ſplit, and fall off. Their colour is from the juice, which fills the internal cellular texture. The ſeem to perſpire through their extremities, and poſſibly throughout their whole ſurface; as we may conclude from the conſtant force of protruſion in their medulla, which, in the plica Polonica, wants a boundary to terminate it. To which add, the luminous ſtreaks or rays that come out from the hairs of an animal electrified. The ſubcutaneous fat or oil ſeems to follow, and tranſude through the medullary tract and pores of the hairs.

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[114] As the ſcales of the epidermis, or its leſs particles, are differently conformed through the various claſſes of animals, inſects, ſerpents, fiſhes, quadrupeds, and the feathers of birds; ſo alſo it is compared with the hairs, which according to the various claſſes of animals, aſſume a difference of nature; being readily changed into true ſcales, as in fiſhes; into feathers, as in birds; into prickles, as in the hedgehog and porcupine; into ſoft wool, &c. The nature of the hairs has been well deſcribed by Malpighius, Ledermuller, &c.

CCCCXXIX. The *nails* are of the nature and fabric of the cuticle; like which, they are alſo inſenſible, and renewable after being cut or having fallen off. They are found placed upon the backs of the ends of the fingers and toes, which they ſupport to make a due reſiſtance in the apprehenſion of objects, having the nervous papillary bodies, that ſerve the organ of touch, placed under their lower ſurface. They ariſe with a ſquare root, intermixed with the perioſteum, a little before the laſt joints, from betwixt the outer and inner ſtratum of the ſkin; and paſſing on ſoft, go out by a lunar cleft in the external plate of the ſkin, where the cuticle returns back, and is partly laid over the outſide of the nail, together with which it is extended forward as an outer covering. The nail itſelf is of a ſoft tender fabric where it firſt ariſes, partly covered by the ſkin; but, by age and contact with the air, it in time hardens into a ſolid, horny, and elaſtic body, compoſed of long hair-like threads, cemented together by interpoſed glue, and diſtinguiſhable from each other by intervening ſulci or furrows, by which one may be able to ſplit them into a number of leſſer orders. The nail thus formed, extends itſelf to the extremity of the finger; and is, in this tract, lined all along internally within its concave ſurface, by an expanſion of the true ſkin, and ſubjacent perioſteum intermixed; the filaments of which ariſe firſt ſhort, and are afterwards continued of a greater length, till they become longeſt of all at the extremity of the nail to which they cohere. Theſe are moſt intimately connected into the root of the nail. Over the outer ſurface of the nail ſome part of the ſkin is again at liberty, and lies under the nail, and diſtinct from it, and has its own epidermis. A furrowed net-work is interpoſed betwixt the ſkin and nail, which is alſo eaſily ſeparable and ſoft, for the protection of the papillæ; from thence the furrows grow gradually harder, ſo that at laſt they can ſcarce be diſtinguiſhed from the nail. The tendons do not reach quite ſo far as the nail.

CCCCXXX. The cellular ſubſtance is without fat, except in a few places to allow a neceſſary motion to the ſkin. Where it is repleniſhed with the fat, it ſerves to defend the warmth of internal parts from the cold air; to render the ſkin moveable upon the muſcles; to fill up the cavities betwixt the muſcles themſelves; and to render the whole body white and uniform. The ſkin, cuticle, and its Malpighian mucus, ſerve not only to limit the external bounds of the body every where; but likewiſe, where they ſeem to be perforated, paſſing inward, they degenerate by degrees[115]. For the cuticle is manifeſtly extended into the anus, urethra, vagina, cornea of the eye, auditory paſſage, mouth, and tongue; nor is it wanting even in the ſtomach itſelf and inteſtines; although, by the perpetual warmth and moiſture, its fabric be altered, and extended or relaxed into their villous covering. Thus the true ſkin is continued into the internal fabric of the palate, tongue, pharynx, noſtrils, vagina, &c. where it degenerates always into a white, thick, pulpy, commonly called nervous, coat of thoſe parts.

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[115] All the parts of the ſkin are not continued upwards through all the holes and openings; for the epidermis is different in the cornea, inteſtines, larynx, and urethra: the ſame holds of the reticula, and of the coriaceous part of the ſkin: the mucous follicles likewiſe make a great difference in the internal places; whereas they are ſebaceous cryptæ externally. The learned Bonn has thrown much light upon this ſubject.

CCCCXXXI. What has been hitherto advanced, is ſufficient to enable us to underſtand the nature of touch. The papillæ, ſeated in the larger winding ridges at the ends of the fingers, regularly diſpoſed in ſpiral folds, are, by the attention of the mind, a little raiſed or erected; as appears from frights or ſhiverings; as we ſee in the nipples of women, in the handling of tangible objects, and by light friction; whereby, receiving the impreſſion of the object into their nervous fabric, it is thence conveyed, by the trunks of the nerves, to the brain. This is what we call the *touch*, whereby we become ſenſible chiefly of the roughneſs of objects; in which ſome perſons have ſo ſharp a ſenſation, that they have been known to diſtininguiſh colours by touching the ſurface only. By this ſenſation we perceive heat, when it exceeds in bodies the heat of our fingers; and weight likewiſe, when it preſſes more than is uſual. Humidity we judge of by the preſence of water; ſoftneſs, by a yielding of the object; hardneſs, from a yielding of the finger; figure, from the limits, or rough circumſcribed ſurface; diſtance, from a rude calculation or eſtimate made by experience, to which the length of the arm ſerves as a meaſure: ſo the touch ſerves to correct the miſtakes of our other ſenſes; but yet it ſometimes errs itſelf, and then the other ſenſes ſhow themſelves to be true guides to the animal without that of touch.

CCCCXXXII. The mucous body of Malpighius moderates the action of the tactile object, and preſerves the ſoftneſs and ſound ſtate of the papillæ. The cuticle excludes the air from withering and deſtroying the ſkin; qualifies the impreſſions of bodies, ſo that they may be only ſufficient to affect the touch, without cauſing pain: and therefore, when it is become too thick by uſe, the ſenſe of feeling is either loſt or leſſened; but if it be too thin and ſoft, the touch becomes painful. The hairs ſerve to defend the cuticle from abraſion; to preſerve and increaſe the heat; to cover and conceal ſome parts, and render the membranes of others irritable, which nature required to be guarded from the entrance of inſects; and perhaps they may ſerve to exhale ſome uſeleſs vapours, or afford a paſſage to the exhaling oil. The nails ſerve to guard the touch, that the papillæ and ends of the fingers may not be bent back by the reſiſtance of tangible objects: at the ſame time they increaſe the power of apprehenſion, and aſſiſt in the handling minute objects. In brute animals, they generally ſerve as weapons of offence, and might be of the ſame uſe to man, if they were not cut off.

CCCCXXXIII. But theſe are not all the uſes of the ſkin. For one moſt important office of that covering is to exhale from the body a large quantity of humours and other matters to be carried off by the air. Accordingly, the whole ſurface · the ſkin, ſweats out a vapour by an infinite number of ſmall arteries, either coiled up into papillæ or ſpread on the ſkin itſelf, which paſs out, and exhale through correſponding pores of the cuticle; although the courſe or direction of the veſſels which pour out this vapour be changed in paſſing from the ſkin to the cuticle. Theſe exhaling veſſels or arteries are eaſily demonſtrated by an injection of water or fiſh-glue into the arteries; for then they ſweat out from all parts of the ſkin an infinite number of ſmall drops, which being transfuſed under the cuticle, rendered impervious by death, raiſe it up into a bliſter.

CCCCXXXIV. In a living perſon, this exhalation is many ways demonſtrable. A clean looking-glaſs placed againſt the warm and naked ſkin, is quickly obſcured by the moiſt vapour. In ſubterraneous caverns, where the air is more denſe, it more plainly goes off into the air, from the whole ſurface of the body, in the form of a viſible and thick cloud.

CCCCXXXV. Whenever the motion of the blood is increaſed, while at the ſame time the ſkin is hot and relaxed, the ſmall cutaneous pores, inſtead of an inviſible

viſible vapour, diſcharge *ſweat*, conſiſting of minute, but viſible drops, which run together into larger drops by joining with others of the ſame kind. But thoſe parts chiefly are ſubject to ſweat which are hotteſt; that is to ſay, where the ſubcutaneous arteries are largeſt, and have a greater action from their reſiſtance, as in the head, breaſt, and foldings of the ſkin. The experiment before mentioned (CCCCXXXIII.), together with the ſimplicity of nature herſelf, joining with the viſible thickneſs or cloudineſs of the cutaneous and pulmonary exhalation (CCCCXXXIV.), ſufficiently perſuades us, that the perſpirable matter and ſweat are diſcharged through one and the ſame kind of veſſels, and differ only by the quantity and celerity of the matter. But together with the ſweat is intermixed the humour of the ſebaceous glands (CCCCXXVII.) and the ſubcutaneous oil, which being more plentifully ſecreted, and diluted with the arterial juice, flows out of an oily and yellow conſiſtence, and chiefly gives that ſmell and colour to the ſweat for which it is remarkable. Hence we find it more fetid in the arm-pits, groins, and other parts, where thoſe glandules are moſt numerous or abundant. Both blood and ſmall ſand have been known to proceed from the ſkin along with the ſweat.

CCCCXXXVI. Concerning the nature of *perſpiration*, we are to inquire by experiments and by analogy with the pulmonary exhalation, which more frequently and abundantly perſpires a vaporous cloud of the ſame kind, more eſpecially viſible in a cold air. That what flies off from the body in this exhalation is chiefly water, appears from experiments, by which the breath, being condenſed in large veſſels, forms into watery drops. Agreeable with this, we find the obſcuring vapour condenſed by a looking-glaſs to be extremely ſubtle, ſo as wholly to fly off again from it; and the ſame is confirmed by the obſtructed matter of perſpiration paſſing off by urine, or frequently changing into a diarrhœa; and from the eaſy paſſage of warm liquors in the form of perſpiration by a hot air, or elſe by the urinary paſſages in a cold air. The water of theſe vapours is chiefly from what we drink, but is in part ſupplied from the inhalation of the ſkin. Frequently, even the particular ſmell of the aliments may be plainly perceived in the perſpiration; and there is alſo an admixture of the electrical matter in every perſon, but in ſome it is more evidently lucid[116].

CCCCXXXVII. But that there are, beſides water, ſome volatile particles intermixed of an alkaline nature, is evident as well as from the nature of our blood, as the conſiderable miſchiefs which follow from a retained perſpiration. This volatile alkaline matter ariſes from the finer particles of the blood, attenuated by perpetual heat and triture, and changed into an acrimonious nature. Theſe afford the ſcent which is cloſely followed by dogs, who would not know their maſters unleſs ſomething of a particular nature perſpired from each perſon.

CCCCXXXVIII. The quantity of our perſpiring moiſture is very large, whether we conſider the extent of the organ by which it is ſeparated, the abundance of vapours derived from the lungs only; or barely take a review of the experiments made by Sanctorius, in which five pounds out of eight, but by other experiments in a colder country from fifty-ſix to thirty ounces, of the food and drink taken into the body in a natural day, were found to fly off by perſpiration only, excluſive of any of the viſible diſcharges, and without making any addition to the weight of the body; but from this weight you muſt deduce that of the ſaliva, mucus of the noſe, and ſweat. But the cutaneous exhalation is even much larger than this; ſince it not only throws off ſuch a quantity of the indigeſted food and drink, but likewiſe what is added to the blood by the way of inhalation (CCCCXLII.),

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[116] It is not yet experimentally proved, whether all the electric matter which we inhale from the air, is communicated ſolely by the lungs, which is the opinion of the celebrated Dagoty; or whether, at the ſame time, we take ſome in by the ſkin: perhaps a greater quantity of this matter is carried off by means of perſpiration through the ſkin, and hence ariſes the lucid nature of certain bodies.

(CCCCXLII.), which entering, often in a very conſiderable quantity, is thus again expelled. But different diſpoſitions of the air, and of the human body, cauſe great variations in thoſe matters. In warm countries, in the ſummer-months, and in young exerciſed perſons, more goes off by tranſpiration from the body, and leſs by the urine. But in cold climates, during the temperate or winter ſeaſons, in aged or inactive perſons, more goes off by the urine than by the inſenſible diſcharge. But in temperate countries, making a computation throughout the whole year, ſomething more is perſpired than what paſſes off by urine; and joining together all the experiments made in different countries, both excretions are almoſt alike. The difference of time after feeding does alſo in ſome meaſure vary the quantity tranſpired; but in general it is moſt copious at that time when the greater part of the digeſted nouriſhment is conveyed into the blood, and there attenuated ſo as to be fit for exhalation. It is naturally diminiſhed in ſleep, even in the warmer climates; but it is increaſed by the heat of bed-cloaths.

CCCCXXXIX. In general, a plentiful and uniform perſpiration, with ſtrength of body, are good ſigns of health; for whenever it abounds from too great weakneſs, it is obſerved to do more miſchief than none at all, if the writings on that head are ſufficiently to be depended on. It is thus a ſign of health, becauſe it denotes a free pervious diſpoſition of the veſſels diſperſed throughout the whole body, together with a complete digeſtion of the nouriſhment, the greater part of which is perfectly attenuated into a vapour. When it is diminiſhed, it indicates either a conſtriction of the ſkin, a weakneſs of the heart, or an imperfect digeſtion of the aliments. Perhaps in too great a perſpiration the nervous ſpirits themſelves are evaporated. This diſcharge is, by moderate exerciſe, increaſed to ſix times that of an idle perſon, even to an half or whole pound in an hour, aided by ſtrong and open veſſels, by warm, watery, and vinous drinks, with animal food of an eaſy digeſtion, and a heavy, temperate, or moderately warm air, aſſiſted with joyful affections of the mind. The contrary of theſe either leſſen or ſuppreſs the perſpiration; as thick ſkin, a moiſt air, or a cold and dry one, with reſt, more frequent bathing than uſual, or from a diarrhœa ſuddenly ariſing, and laſtly from a nervous concuſſion from a diſagreeable affection of the mind. However, the continuance of life does not depend on a ſcrupulous exactneſs in the quantity of this diſcharge, which is ſo eaſily increaſed or diminiſhed by ſlight cauſes; which is ſhut up by paints in many Indian nations, and is inconſiderable in many animals without any ſenſible injury. When it is ſuppreſſed, it does a prodigious deal of miſchief in fevers of a bad kind; it hurts chiefly by its putreſcent qualities, which are retained by ſuppreſſed perſpiration.

CCCCXL. The ſweat is evidently of a ſaline nature; as appears both from the taſte, and from the minute cryſtals which ſhoot upon the cloaths of ſuch as work in glaſs-houſes; as well as by diſtillation, which ſhows the ſweat to be of an alkaline nature. Hence it is, that by this diſcharge the moſt malignant matter of many diſeaſes is thrown off from the body. But, in reality, ſweat is always a preternatural or morbid diſcharge, from which a perſon ought always to be free; unleſs by violent exerciſe, or other accidents, his conſtitution is for a ſhort time thrown into a diſeaſed ſtate. Nor is it unfrequent for ſweats to do conſiderable miſchief in acute diſeaſes; by waſting the watery parts, and thickening the reſt of the blood, at the ſame time that it renders the ſalts more acrimonious. By a too violent motion of the blood, the ſweat is rendered extremely fetid; and is ſometimes even red, or mixed with blood itſelf: being electrized, it ſometimes is lucid.

CCCCXLI. The uſes of perſpiration are, to free the blood from its redundant water, and throw out thoſe particles, which, by repeated circulations, have become alkaline or otherwiſe acrimonious; and poſſibly to exhale therewith an extremely volatile oil, prepared from the ſame blood. The ſame perſpiration likewiſe qualifies and ſoftens the cuticle, which is a neceſſary medium extended before the tender ſenſible papillæ.

CCCCXLII. But the ſame ſkin that makes this exhalation into the air, is likewiſe full of ſmall veſſels, which inhale or abſorb thin vapours from the air, either perpetually, or at leaſt when it is not very cold; more eſpecially when the air is damp, the body unexerciſed, the mind oppreſſed with grief, or both under conditions contrary to thoſe which increaſe perſpiration beforementioned (CCCCXXXVIII.) Theſe veins are demonſtrated by anatomical injections, which, if thin or watery, ſweat through them as through the arteries, if it was watery and thin: moreover, the manifeſt operation of medicines, pervading the air, or applied to the ſkin, prove the ſame; ſuch as the vapours of mercury, turpentine, ſaffron, Bath-waters, mercurial plaſters, tobacco, coloquintida, opium, cantharides, arſenic, with the fatal effects of contagious or other poiſons entering through the ſkin; as in the venereal infection: to which add, the living of animals almoſt without drink in hot iſlands, which abound with moiſt vapours; from which, however, they ſweat and piſs plentiful enough. Laſtly, ſome extraordinary morbid caſes have demonſtrated this, in which a much greater quantity of urine has been diſcharged than the quantity of drink taken in; in which you may believe that the moſt open paſſages ſerved for inhalation; that new ones were generated, is not credible. The proportion of this inhalation is difficult to aſſign; but that it is very great in plants, more eſpecially in the night-time, appears evidently from certain experiments.

CCCCXLIII. Theſe cutaneous veſſels, both exhaling and inhaling, are capable of contraction and relaxation by the power of the nerves. The truth of this appears from the effects of paſſions of the mind; which, if joyful, increaſe the circulation, and relax the exhaling veſſels, ſo as to yield eaſier to the impulſe of the blood; from whence, with a ſhortening of the nerves, there follows a redneſs, moiſture, and turgeſcence of the ſkin. Thoſe paſſions, on the contrary, which are ſorrowful, and retard the circulation, contract the exhaling veſſels; as appears from the dryneſs and corrugation of the ſkin, like a *gooſe-ſkin*, after frights; and from a diarrhœa cauſed by fear. But the ſame affections ſeem to open and increaſe the power of the inhaling veſſels, whence the variolous or peſtilential contagions are eaſily contracted by fear.

CHAP. XIV.

Of the TASTE.

CCCCXLIV. THE organs of taſte and touch differ but ſlightly. By certain experments it appears, that the power of taſte is exerciſed by the tongue chiefly[117]; for even ſugar applied to any other part of the mouth, excites ſcarce the leaſt ſenſe of taſte in the mind: neither will any other ſapid body, unleſs it contains ſomething vehemently penetrating; in which caſe the palate, root of the tongue, uvula, and likewiſe the œſophagus, are affected with the taſte. That ſenſation which is ſometimes excited in the ſtomach, œſophagus, and fauces, by the regurgitation of the aliments, ſeems alſo to belong to the tongue; to which the ſapid vapours are ſent back, uncommonly acrid and penetrating: and even that ſenſe which is ſometimes occaſioned in the ſtomach, œſophagus, and fauces, from a riſing of the aliments, ſeems alſo to be owing to the tongue, to which the taſtable vapours are conveyed.

CCCCXLV. Only the upper and lateral edges of the *tongue* are fitted to exerciſe the ſenſe of taſte. But by the *tongue* we underſtand a muſcular body, broad and ſulcated in man, and lodged in the mouth, whoſe poſterior and lower parts are variouſly connected to the adjacent bones and cartilages, while it remains moveable in its anterior and upper part. In thoſe portions of the tongue, which make the organ of taſte, the ſkin grows to the adjacent muſcular fibres, being continued from the ſkin of the face and mouth; only here it is always ſoft and pulp-like, from the perpetual warmth and moiſture. From this ſkin ariſe innumerable nervous *papillæ*, of a more conſiderable bulk here than in other parts. Of theſe there are ſeveral kinds: the firſt of them are diſpoſed in a rank on the back part of the tongue, on each ſide of the foramen cæcum [118]. Theſe, ſurrounding that opening like a circle, are for the moſt part like an inverted cone, having a deep ſinus in their middle; but are otherwiſe hard, and but indifferently diſpoſed for taſting, although you can eaſily trace the nerves to them. There are ſome other papillæ of the ſame kind found ſcattered before theſe upon the back of the tongue.

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[117] Nowhere indeed upon the ſkin, when the epidermis is taken off, do we feel the taſte of bodies; but taſte is by no means confined to the tongue alone. For on whatever part of the mouth, palate, or cheeks, you apply a ſapid body, you will not perceive the ſenſe of pain, but of the taſte; even of ſome bodies, as arum, pepper, &c. it will be ſtronger and more diſtinct than any where elſe.

CCCCXLVI. Theſe degenerate into a kind of papillæ like muſhrooms, leſs and ſlenderer than the former, of a very cylindric and ſomewhat oval figure, placed at ſome ſmall diſtauce from each other, upon the upper ſurface of the tongue, where they grow ſharper pointed as they lie more forwards, and are moſt numerous on the ſides of the tongue. The third ſort of papillæ are of a conical figure, which abound moſt in number among the former, and are ſpread largely over the tongue. Theſe have their apices ſomewhat inclined and fluctuating before, towards the tip of the tongue; theſe are likewiſe moſt numerous in the ſides of the tongue, though there are ſome alſo behind the blind foramen. They are highly ſenſible, and make the true organ of taſte: other papillæ intervene, which are partly conical, and partly ſhaped like threads; and ſome of the conical ones are greater, and the others grow always leſs and leſs[119].

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[118] The number of theſe papillæ vallatæ are by no means conſtant; for the moſt part they are ſeven or eleven, the middle one of which is on the very foramen cæcum: however, it is not rare to find a greater number, and then it is increaſed beyond fifteen or ſeventeen.]

CCCCXLVII. Theſe papillæ have doubtleſs ſmall nerves detached into them, beſides numerous veſſels, although they are difficult to trace; for we obſerve, that larger nerves go to the tongue than almoſt in any inſtance which we have in other parts. For beſides the nerve of the eighth pair, which, being one of the principal of the three branches, deeply enters the baſis of the tongue, covered by the cerato-gloſſus, near the os hyoides, there is alſo a conſiderable nerve that goes to the tongue and its muſcles, from the ninth pair; which having inoſculated with the firſt nerve of the neck, and with the large cervical ganglion, it ſends a branch downward, and frequently joins the eighth pair; but conſtantly communicates with the ſecond and third of the neck, from whence its branches aſcend to the muſcles ariſing from the ſternum, and frequently communicate with the phrenic nerve; after which, the reſt of its trunk goes to the tongue[120]. This communicates, by many branches, with the fifth pair in the cerato-gloſſus, and is more eſpecially ſpent on the genio-gloſſus. Laſtly, the third branch of the fifth pair having ſent up or received the cord of the tympanum, and given other branches to the internal pterygoides, with the maxillary and ſublingual glands, paſſes with its principal trunk behind the cerato-gloſſus, where it joins the ninth pair, and enters the tongue deeply, in company with the artery; together with which it is extended to the tip of the tongue, where it becomes cutaneous. To this nerve, therefore, if there be any prerogative or preference, the ſenſe of taſte is to be more eſpecially aſcribed, which is confirmed from obſervations on ſome diſeaſes[121]. Laſtly, the nipples or papillæ of the tongue are of a hard texture, each papilla having its pulpy fabric made up by a number of ſmall nerves, arteries, and veins, conjoined or wound up with a firm cellular ſubſtance into a button, or protuberance, of which many are required to make up one large papilla.

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[119] Albinus has properly added to theſe three claſſes of papillæ a fourth, which lies on the ſides of the tongue, and conſiſt of ſmall, almoſt concentric ſlits, again interſected into ſmaller ones: theſe pretty clearly ſhow the tongue's analogy with the ſkin.

[120] In ſeven bodies one is found, in which a filament goes from the ninth pair to the phrenic.

CCCCXLVIII. The arterial and venous down which runs between the papillæ are for the purpoſes of exhalation; and have nothing to do with the taſte, farther than that they ſeparate from the blood a liquor fit for diſſolving ſalts, and keeping moiſt the papillæ proper for taſte: this liquor they pour out on the back of the tongue. On the upper and back part of the tongue are ſeated many ſimple, round, muciferous glands, having one or more open outlets, which are completed by an hemiſpherical membrane, and the fleſhy part of the tongue. Some of theſe open into the obſcure, blind, and uncertain figured hollow, which is placed in the middle between the largeſt papillæ (CCCCXLV.), and commonly contains ſome of them.

CCCCXLIX. Over the papillæ of the human tongue is ſpread only a ſingle mucous and ſemipellucid covering, which ſtrictly adheres to them, and ſerves them as a cuticle. But, in brute animals, a perforated mucous network receives the papillæ, which are in a manner wrapped up in caſes or capſules of this mucous body covered with the cuticle.

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[121] In moſt of the ſenſitive organs, it is confirmed and proved by long experience, that, out of ſeveral nerves going to an organ, one only ſerves for exerciſing ſenſe: that the optic conſtitutes the primary ſeat and inſtrument of ſight, though we know that ſeveral nerves enter the eye: that the portio mollis is the nerve fitted for hearing, although the portio dura likewiſe paſſes through the ear: that the olfactory nerve does the office of ſmell, notwithſtanding a remarkable number of branches coming from the fifth pair to the membrana pituitaria: and ſo in like manner the ninth pair or middle lingual is appointed for taſte, although conſiderable portions from the gloſſopharyngæus and fifth pair are diſtributed through the tongue. With all this I agree; but the noted hiſtory of Columbus has too fully proved, that little credit is to be given to morbid affections, when inveſtigated and aſſerted by ſingle obſervations alone.

CCCCL. Under thoſe papillæ are ſpread the muſcles which make the fleſhy body of the tongue; which are very numerous, and hardly extricable in the human tongue: in the lower part, it is in a great meaſure made up of the genio-gloſſus muſcle extended outwards from the meeting of the chin, and diſtributed like rays into the ſubſtance of the tongue. The upper and lateral parts are compoſed of the ſtylo-gloſſus, whoſe fibres run to the tip of the tongue; which in its middle part, betwixt the former muſcles, is compoſed of one proper to itſelf, called *lingualis;* which ariſing from before the pharynx and origin of the ſtylo-gloſſus, only lower, goes out forward, and, terminating betwixt the ſaid genio-gloſſus and ſtylo-gloſſus, makes up a very conſiderable part of the tongue. The back part of the tongue is made up of the fibres of the cerato-gloſſus, which aſcend upward and backwark; which ends between the ſtylo-gloſſus and lingualis, being included between them: and to this is joined the chondro-gloſſus, a muſcle entirely different, which ariſes from the ſmall bones, and next adjacent baſis of the os hyoides; from whence paſſing outward, with its lateral portions, covered by the genio-gloſſus, it joins the ſtylo-gloſſus, and diſappears in the tongue. By the action of theſe muſcles the whole tongue is moveable in all directions, and capable of figuring its own ſubſtance, ſo as to form a hollow, by the elevation of the ſtylo-gloſſi, which it again flattens by the cerato-gloſſi, but contracts itſelf into a narrow and almoſt cylindrical figure, by the tranſverſe fibres from one ſide to the other, together with which there are many other orders of fibres, intermixed with a thick fat, ſo that they cannot be traced in the human tongue.

CCCCLI. The *arteries* of the tongue are numerous. One that is larger and deeper aſcends in a ſerpentine courſe from the outer carotid, and extends to the tip of the tongue; and a leſſer ſuperficial artery, incumbent on the ſublingual gland, either ariſes from, or inoſculates with, the preceding. Behind, there are various ſmall branches derived from the poſterior labials; and from the branches proper to the lips, or thoſe of the tonſils. The veins of the tongue are variouſly wove, and difficult to deſcribe; ſome of which, lying deep, accompany the nerve of the ninth pair; and others, that are ſuperficial, accompany the mental artery, and, inoſculating with the former, ſends out the ranular vein; but all of them meet together in a large vein, which is one branch of the internal jugular coming from the brain. Theſe veins variouſly communicate with the adjacent networks belonging to the tonſils, pharynx, thyroide gland, and ſkin; and in the back of the tongue, before the epiglottis, there is a communication betwixt the right and left ſide of the venal plexus. I find lymphatic veſſels rather in the neighbourhood of the tongue than in the tongue itſelf.

CCCCLII. The *papillæ* of the tongue, which are larger and ſofter than thoſe of the ſkin, perpetually moiſt, perform the office of touch more exquiſitely than thoſe of the ſmall and dry cutaneous papillæ; and from hence the tongue is liable to a ſharper degree of pain: moreover, naked ſalts are not otherwiſe perceived than under a ſenſe of moiſture, or of pain. But the papillæ of the tongue being raiſed a little protuberant, to perform the office of taſte, from ſalts diſſolved in water, or ſaliva, and applied againſt their tips or ſummits, are affected in a particular manner; which being diſtinguiſhed by the mind, and referred to certain claſſes, are called *taſtes*, either ſour, ſweet, rough, bitter, ſaline, urinous, ſpirituous, aromatic, or pungent and acrid, of various kinds, inſipid, putrid, and others reſulting partly from pure ſalts, and in part from an intermixture of the ſubtile animal or vegetable oils, variouſly compounding and changing each other. If it be inquired, Whether the diverſity of taſtes ariſes from the different figures which are natural to ſalts [122]? and whether this does not appear from the cubical figure in which ſea-ſalt ſhoots, the priſmatical figure of nitre, or the particular configuration of vitriol, ſugar, &c.? we anſwer, That this does not ſeem probable, for even taſteleſs cryſtals have their particular configurations; and the taſte ariſing from very different ſalts, and differently qualified objects of this ſenſe, are too much alike each other, and at the ſame time too inconſtant or changeable, to allow ſuch a theory; as for example, in nitre. The mechanical reaſon, therefore, of the diverſity of taſtes, ſeems to reſide in the intrinſic fabric or appoſition of their elements, which do not fall under the ſcrutiny of our ſenſes.

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[122] Whoever would compare the elegant obſervations of Baker, Ledermuller, Luchtmans, and Gleichen, upon the figures of ſalts, will

CCCCLIII. But the nature or diſpoſition of the covering with which the papillæ are clothed, together with that of the juices, and of the aliments lodged in the ſtomach, have a conſiderable ſhare in determining the ſenſe of taſte; inſomuch, that the ſame flavour does not equally pleaſe or affect the organ in all ages alike, nor in perſons of all temperatures; nor even in one and the ſame perſon at different times, who ſhall be differntly accuſtomed in health or variouſly diſeaſed. In general, whatever contains leſs ſalt than the ſaliva itſelf, ſeems inſipid.

CCCCLIV. The ſpirituous parts, more eſpecially of vegetables, either penetrate into the papillæ themſelves, or elſe are abſorbed by the adjacent villi of the tongue; as may appear from the ſpeedy reſtitution of the ſtrength by vinous or aromatic liquors of this kind, even before they are received into the ſtomach.

CCCCLV. Nature deſigned the difference of taſtes to be felt by the tongue, that we might know and diſtinguiſh ſuch foods as are moſt ſalutary: for in general, there is not any one kind of aliment healthy that is of a diſagreeable taſte; nor are there any ill taſted matters that are fit for our nouriſhment. For it muſt be obſerved, that we here take no notice of exceſs, by which the moſt healthy

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will be grieved to imagine, that ſo ſimple and eaſily conceived a theory is not capable of explaining the diverſity of taſtes.

healthy food may be prejudicial. In this manner nature has invited us to take neceſſary food, as well by the pain called *hunger*, as by the pleaſure ariſing from the ſenſe of taſte. But brute animals, who have not like ourſelves the advantage of learning from each other by inſtruction, have the faculty of diſtinguiſhing flavours more accurately, by which they are admoniſhed to abſtain cautiouſly from poiſonous or unhealthy food; and therefore it is that herbivorous cattle, to which a great diverſity of noxious plants is offered amongſt their food, are furniſhed with ſuch large and long papillæ of ſo elegant a ſtructure in the tongue, which are not ſo neceſſary to man.

CHAP. XV.

Of SMELLING.

CCCCLVI. THE ſenſe of ſmelling likewiſe conduces to the diſtinguiſhing prejudicial from ſalutary food. By it we both diſcover and are admoniſhed to avoid, before it comes to our taſte, what might be otherwiſe dangerous; and we are eſpecially enabled to avoid any thing of a putrid tendency in our victuals, which to us is of a moſt peſtilent nature, and likewiſe to diſcern what are grateful and wholeſome aliments; although cuſtom has rendered it more remarkable among brute animals than among men. For men who have been brought up wild by themſelves, without debauching the ſcent by a variety of ſmells, have been obſerved to poſſeſs that diſtinguiſhing faculty in a very infallible degree. Finally, the powers and virtues of medicinal plants are hardly to be better known than by the ſimple teſtimony of taſting and ſmelling. From hence it is, that in all animals theſe organs are placed together; and from hence the ſmelling is ſtronger, and the organs larger, in thoſe animals which are to ſeek their prey at a conſiderable diſtance, or to reject malignant plants from among thoſe that are fit for food.

CCCCLVII. The ſenſe of ſmelling is performed by means of a ſoft pulpy membrane, full of pores and ſmal veſſels, which lines the whole internal cavity of the noſtrils, being thicker upon the ſeptum and principal convolutions, but thinner in the ſinuſes. Within this membrane are diſtributed abundance of ſoft nerves throughout the middle of its fabric, from the firſt pair (CCCLVII.)[123], which deſcend through the holes of the os cribroſum into the ſeptum narium; but in ſuch a manner, that it is very difficult to trace them to their extremities and into the ſeptum. Other lateral nerves come from the ſecond branch of the fifth pair and its branches, from that which lies tranſverſe in the pterygoide canal, and from another which deſcends through the canals of the palate; and ſome from the infra-orbital branch in the maxillary ſinus, from the dental branch, and from the anterior nerve of the palate. Moreover, the fore-part of the ſeptum has a ſmall twig from the ophthalmic of the firſt branch belonging to the fifth pair[124].

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[123] To end the diſpute, whether the olfactory nerve be hollow, as Hoffman, Collins, Slevogt have aſſerted, and which Vieuſſens, Brunner, and Haller have denied; it is to be obſerved, that in ſome caſes it is found quite hollow, ſo that it may be diſtended by blowing in at the cribriform plate. A caſe of this kind M. Sommering ſaw along with me: but in moſt ſubjects I found it ſolid, and unable to be diſtended by any means.

[124] We ſee diſtinctly the little twigs of nerve, which enter the inſide of the noſtrils from the fifth pair. Haller has already ſpoken of the pterygoide and palatine ramifications. I have ſeen ſent off from the infra-orbitalis two, three, or four filaments, along with the accompanying veſſels, through that part of the membrana pituitaria which covers the antrum Highmorianum. From the ophthalmic branch, beſides the ethmoidal nerves which run through the membrana Schneideriana of the ethmoidal cells, and may be diſtinguiſhed by an elegant whiteneſs, I have ſeen in ſome bodies, ſpecimens of which I have now by me, a branch ſent off from the frontal branch before it has become the ſupra trochlearis, which, along with the infra-trochlearis, turns from the naſal into a ganglion, from which a twig runs into the frontal ſinus. Blumenback has already mentioned this nerve according to my obſervation. The reaſon, perhaps, why it is not found in all ſubjects, is owing partly to its own tenderneſs and ſmallneſs, and partly to the violence uſed in the ſeparation of the bone.

CCCCLVIII. The arteries which go to the noſe are many: from the internal maxillary branches; from the three naſal ones, to wit, the upper and both ethmoidal branches; alſo from the frontal, naſal, and ſide branches; from the leſſer ophthalmic branch of the internal carotid; from branches of the palatine artery; from the infra-orbital within the ſinuſes; and from the ſuperior dental one. It is proper to theſe arteries very eaſily and very plentifully to ſweat out blood, without any conſiderable injury to the veſſels themſelves. The veins run together in company with arteries, and form a large plexus, by uniting upon the external pterygoide muſcle, and communicate with the ſinuſes of the dura mater; from whence they open together into the outer branch of the internal jugular. The arteries ſupply the nouriſhment, warmth, and mucus, neceſſary to theſe parts.

CCCCLIX. The formation of the human head into that of a roundiſh figure, has in us given to the organ of ſmelling but a ſmall extent of ſurface[125]; but to enlarge this the more, nature has made the internal parts of the noſe variouſly hollow and complicated, in a ſurpriſing manner. Firſt then, by the *nares* we underſtand the multiform cavity, which begins before from the noſtrils, and, extending tranſverſely backward over the roof of the palate under the os cribroſum, terminates at the cavity of the fauces. This cavity is divided into two by a ſeptum or partition of bone, which deſcends above from the plate of the cribroſum, but below is formed by the vomer, and in its fore-part is completed

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[125] I am always ſtruck with admiration, when I compare the organs of ſmell in ſome quadrupeds with thoſe of man. For as in man the cavity of the cranium, which is the ſeat of the brain, is to the face almoſt as three, or two to one; but in brutes, as the horſe, cow, ſow, as one almoſt to ſix, eight, or nine; ſo in man the circumference of the noſtrils is to the whole globe of the head as one to fourteen or ſixteen; in brutes, on the contrary, as three or two to one; or in ſome, as one to one. Therefore, the anatomical reaſon is plain, why moſt animals ſmell more acutely than man, although he may have weakened his ſmelling by no bad cuſtom.

by a triangular cartilage, whoſe ſurface is largely extended and very ſenſible.

CCCCLX. Moreover, the lateral ſurfaces of the nares are increaſed by the ſpiral windings of the *oſſa turbinata*[126]*;* the uppermoſt of which are ſmall turns or folds of a ſpiral figure from the upper part of the os cribroſum. The middle fold belongs to the ſame, ſomewhat oblong like a ſhell, internally convex, externally concave, riſing into an edge on each ſide; all over rough with little ſinuoſities or excavations, and inwardly filled with ſpungy cells or receſſes; the whole being ſuſpended in a tranſverſe poſition, and ſupported by particular eminences in the bones of the palate and upper jaw. The lowermoſt turbina, ſomewhat like the middle ones, do like them reſemble the figure of a limpet ſhell, but longer; for the moſt part divided from the former, but ſometimes conjoined by a bony plate, which is moſt frequently of a membranous nature. This bony appendix, being extended upwards in a ſquare form, ſerves to complete the maxillary ſinus.

CCCCLXI. From hence the cavity of the nares is enlarged or dilated by various ſinuſes, which are a ſort of receſſes or appendages to the whole. And firſt, the frontal or uppermoſt ſinuſes, which are not always preſent, are of an irregular figure[127], intercepted betwixt the anterior and poſterior plate of the frontal bone, where it forms the ſuperciliary protuberances; and theſe, being not round in a fœtus, ſeem to ariſe from the action of the corrugator and other muſcles, which draw the anterior plate of this bone outward, ſo as to increaſe the diploë into large cells, in the ſame manner as we obſerve in the maſtoide proceſs. Theſe open in the upper part of the nares into the interior cell of the os pyraceum. There are inſtances of their being totally wanting, and growing after the birth.

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[126] The oſſa turbinata are commonly counted three; but if indeed we take any turning of the bone in the cavity of the noſtrils for a bone, their number muſt be increaſed to four, and ſeveral paſſages alſo are formed.

[127] The frontal ſinuſes ſometimes grow to a remarkable ſize. Laſt winter, in a male ſubject, they extended not only over all the orbit, that the plates of the orbitary proceſs of the os frontis were diſtended two or three lines; but what is ſtill more ſurpriſing, they penetrated into the alæ minores of the ſphenoid bone, and communicated with the ſphenoidal ſinuſes by a diſtinct canal going to the inner ſide of the foramen opticum. In theſe ſinuſes, worms of various kinds lodge; which I aſſert, partly from my own experience, in which I ſaw in a boy of thirteen years of age ſome lumbrici, and leeches in dogs, which is likewiſe proved by other learned men.

CCCCLXII. In the ſecond place come the *ethmoidal ſinuſes;* which are four or more on each ſide, in the outer part of the os cribroſum, like the cells of an honey-comb; completed above by the cellular middle part of the os frontis, and before by the os unguis; behind, by the bone of the palate and ſphenoid bone; from whence they open by many ſmall tubes, placed one above another in a tranſverſe poſition, into the upper part of the nares. With theſe are continuous the cells in the pavement or bottom of the *orbit*, and thoſe engraved in the os planum and maxillare are continued from them outward. In a third place, this ſinus is contiguous on each ſide with the cavity or *ſinus of the multiform bone*, extending largely on each ſide towards the os cribroſum and palatinum, which is itſelf formed in a dry preparation, by the cartilage of large extent in the fœtus, and by a ſolid bone, which gradually widens under the ſella turcica, with an ample cell either ſingle or divided; and opening forward by its aperture or foramen, into the ſuperior part of the meatus narium.

CCCCLXIII. The laſt, lowermoſt, and biggeſt ſinus, which in a fœtus is inconſiderable, but in an adult very large, is that formed in the bone of the *upper jaw* by ſeveral thin bony plates. The opening of this into the noſe is betwixt the os unguis bone of the palate and the proper lamella or plate which accedes to it from the bottom of the os turbintatum. Which opening is ſo much leſſened by the ſurrounding membranes, as to form only a moderate round aperture in the ſpace betwixt the middle and bottom of the os ſpongioſum. But it likewiſe ſends forth an hollow appendix, tending forwards, under the orbits which the os planum, unguis, and papyraceum complete, communicating likewiſe with the ethmoidal cells, and open behind the oſtium lachrymale.

CCCCLXIV. The nerves of the noſe, being almoſt naked, required a defence from the air, which is continually drawn through the noſtrils, and blown out again by the uſe of reſpiration. Nature has therefore ſupplied this part, which is the organ of ſmelling, with a thick inſipid mucus, very fluid in its firſt ſeparation, and not at all ſaline, but, by the air condenſing into a thick dry cruſt, more conſiſtent here than in other parts of the body. By this mucus the nerves are defended from drying and from pain. It is poured out from many ſmall arteries of the noſtrils; and depoſited partly into numerous cylindrical ducts, and partly into round viſible cryptæ or cells ſcattered all over the noſtrils. The ſame flows out all over the ſurface of the olfactory membrane, which is therewith anointed on all ſides. In the ſeptum runs down forward a long ſinus to a conſiderable length, which is common to many muciferous pores: this mucus is accumulated in the night time; but in the day expelled by blowing the noſe, or ſometimes more powerfully by ſneezing; and may offend by its exceſs or tenuity, or irritate by too great thickneſs the very ſenſible nerves, from whence a ſneezing is excited for its removal. But the ſinuſes of this part, which abound with mucus, are this way variouſly evacuated, agreeable to the different poſtures of the body; by which always ſome of them are at liberty to free themſelves, whether the head be erect, or inclined forward, or laterally; yet ſo, that generally the maxillary and ſphenoidal ſinuſes are more difficultly emptied than the reſt. Moreover, the tears deſcend, by a channel proper to themſelves, into the cavity of the noſe, by which they moiſten and dilute the mucus.

CCCCLXV. To the extreme parts of the nares or organs of ſmelling is prefixed the noſe; lined inwardly with a membrane of the ſame nature; and compoſed of two bones, and uſually ſix cartilages, two of which are continued together into the middle ſeptum, (CCCCLIX.). Theſe cartilages render the noſe moveable by its proper muſcles, ſo as to be raiſed and dilated by a muſcle common to the upper lip, and to be contracted together into a narrow compaſs by the proper depreſſor and compreſſor muſcle pulling down the ſeptum. Thus we ſee that this organ projects, like an engine in the air, for the reception of ſmells, and may be dilated in proportion to the quantity of inhaled air, and again contracted, when it is expelled in the ſame abundance.

CCCCLXVI. The air, therefore, filled with the ſubtle and inviſible effluvia of bodies, conſiſting of their volatile, oily, and ſaline particles, is, by the powers of reſpiration (CCLXV.), urged through the noſe, ſo as to apply the ſaid particles to the almoſt naked and conſtantly ſoft olfactory nerves, in which a kind of feeling is excited, which we call *ſmelling*: and by this ſenſe we diſtinguiſh the ſeveral kinds of oils, ſalts, and other matters, difficultly reducible to claſſes, which hereby we perceive indiſtinctly; whence they are difficultly recalled to memory, though the odours already eſtabliſhed are ſufficient enough for our purpoſes. This ſenſe ſerves to admoniſh us of any pernicious putrefaction; of any violent acrimony; or of a mild, ſoapy, and uſeful diſpoſition in bodies. And as ſalt, joined with an oil, is the object of taſte; ſo a volatile oil, aided with ſalts, ſerves to excite ſmells: whence the affinity of the two ſenſes, which conjunctly aſſiſt and move each other, may be eaſily underſtood. But volatile particles chiefly are diſtinguiſhed by ſmell, and fixed ones by the taſte; perhaps becauſe the thick mucous cuticle, ſpread over the tongue, intercepts the action of the more ſubtle ſaline effluvia from acting upon the taſte, which yet eaſily affect the ſofter and leſs covered nerves of the internal noſe. We are ignorant of the reaſon why ſome ſmells pleaſe, and others diſpleaſe; perhaps cuſtom may have ſome effect in this caſe.

CCCCLXVII. Smells have a very ſtrong action, but of ſhort continuance; becauſe they are applied immediately, by the moſt minute particles, to nerves which are very near to the brain itſelf, and almoſt naked; from thence too proceeds the force of poiſonous vapours, and the refreſhment from agreeable odours, by which ſome perſons are effectually recalled to themſelves out of a dead ſwoon, or even after drowning. From hence comes that violent ſneezing, which often ariſes from acrid particles; and a looſeneſs or purging of the bowels, from the ſmell of ſome medicines, with the power of particular antipathies. From hence is derived the pernicious effects of exceſſive ſneezing, more eſpecially blindneſs, from the near conſent or ſociety of the nerves. But amongſt the various parts of the noſe, the ſeptum, and more eſpecially the os turbinatum, have a conſiderable ſhare in the organ of ſmelling: ſince theſe are parts multiplied in quick ſcented animals, ſo as to form beautiful ſpires in hounds and other quadrupeds; and in fiſh, who ſmell by water, they are formed like the teeth of a comb, in an elegant manner.

CHAP. XVI.

Of HEARING.

CCCCLXVIII. AS the ſenſe of ſmelling diſtinguiſhes the ſmall bodies which float in the air, ſo that of hearing perceives the elaſtic tremors or impulſions of the air itſelf. Therefore, we obſerve the ſenſitive organ of the ear to be compoſed in a different manner from that of any of the other ſenſes; as it is made up, for the moſt part, either of hard bones or elaſtic cartilages and membranes, which are the moſt exquiſitely enabled to receive and communicate the neceſſary tremors.

CCCCLXIX. The external part of this organ, called the *auricle* or outer ear, is a cartilaginous funnel, connected, but with a ſort of mobility, before and behind, to the bones of the temple, by means of a ſtrong cellular plate, and likewiſe by its own proper ligaments and muſcles; but the mobility of this part is diminiſhed by cuſtom. This cartilage is of a very compound figure; in general of a kind of oval figure, yet marked with ſpirals ſtanding up, and hollows interpoſed, to which other hollows and ridges correſpond in the oppoſite ſurface. The outer eminence, called *helix*, begins above by a looſe tape, is carried round at liberty about the edge of the upper part of the cartilage, upon the poſterior ſide of which it terminates in the ſame looſe manner. Within the body of the cartilage, ſurrounded by the former, ariſes a bifurcated eminence, meeting together in one, called the *anthelix*, which terminates in a ſmall and ſhort tongue called the *antitragus*. The remaining part of the ear, called the *concha* or ſhell, is, before, hollow; behind, convex; growing gradually deeper, with a crooked line or ridge running through its middle, under the denomination of the concha, which is immediately joined with the meatus auditorius; before which ſtands a round moveable appendix of the cartilage, as a defence, called the *tragus*.

CCCCLXX. This whole cartilaginous body of the outer ear is only ſurrounded by a thin ſkin, and an empty cellular ſubſtance; it is repleniſhed with many ſebaceous glandules, which ſupply an ointment. This part is governed or directed by certain muſcles, which generally loſe their uſe and action, from the cuſtom of binding the head in children, which we are otherwiſe to ſuppoſe they were deſigned by nature to perform. The uppermoſt of theſe muſcles ariſes thin from the frontal and from the aponeuroſis of the cranium; whence it is broadly ſpread over the aponeuroſis of the temporal muſcle, and is inſerted into the anthelix, or neighbouring helix, at the ſide of the anonymous cavity. The poſterior muſcles, which are two or three, more or leſs, are more robuſt than the former in a tranſverſe poſition; and, ariſing from the ſame aponeuroſis, are inſerted into the convex part of the concha near the maſtoidal bone; the cavity of which concha they, doubtleſs, are deſigned to open or enlarge. The anterior muſcle is one of the leaſt, which, being ſpread upon the aponeurosis of the temporal, is inſerted almoſt tranſverſely into the origin of the helix and neighbouring concha. But the leſſer muſcular portions, which, though ſhort, and not very conſpicuous, look of a red colour, are probably of uſe to make ſome change in the figure of this part. The tranſverſe muſcle of the outer ear, which, for a long way, conjoins the helix with the anthelix, ſerves to open the auricle. The antitragic muſcle, deſcending from the root of the anthelix to the antitragus, ſerves to widen the entrance of the concha. The tragicus, which lies upon the tragus, opens the entrance to the auditory paſſage; and the ſmall muſcle of the larger notch or inciſure, that lies betwixt the two cartilages of the auditory paſſage, forming the tragus and antitragus, ſerves to bring them nearer together, and to render the meatus itſelf more tenſe and elaſtic. The remaining muſcles, the longer or larger, and the leſſer of the helix, have hardly any great uſe; unleſs it be to tighten or brace up the cartilages whenever we attend or liſten to the hearing of weak ſounds; and, by drawing together the cartilages, they likewiſe render the auditory paſſage more firm.

CCCCLXXI. To the concha is connected the *meatus auditorius*, ſomewhat of a round compreſſed figure, leſſening as it bends inward; for a conſiderable part bony, and bent forward in its middle. But, in its anterior and outer part, it is, in ſome meaſure, made up by three imperfect rings, ariſing from the concha and tragus, and united together, and to the bone itſelf, by intermediate fleſh, membrane, and cartilage. Upward and backward, the meatus is completed by a mere membrane. This is the ſtate of it in adult perſons; for, in the fœtus and new-born infants, the meatus is wholly cartilage, and becomes afterwards, in part, a bone by degrees.

CCCCLXXII. Through the auditory paſſage are continued the cuticle and true ſkin, gradually extenuated and exactly ſtetched over the ſurface of the bone, by which it is rendered extremely ſenſible of any itching pleaſure or pain; and, being repleniſhed with irritable hairs, is by them admoniſhed of any ſordes or wax abounding, and guarding from the entrance of ſmall inſects. But, in the cellular ſubſtance under the ſkin, which is here more firm, and makes up the greater part of the membrane (CCCCLXXI.), in a ſort of reticular manner, are ſeated numberleſs round follicles or cells of a yellow colour, which pour out their contents by ſhort ducts into the cavity of the auditory paſſage; at firſt of an oily conſiſtence, but afterwards it becomes more thick, bitter, and inflammable like wax. This liniment defends the ſenſible ſkin and membrane of the tympanum from injuries of the air, and keeps out or catches any ſmall inſects; but, when accumulated in too great abundance in thoſe who are ſlothful or uncleanly, it may be the cauſe of deafneſs, or a difficulty of hearing.

CCCCLXXIII. Into this funnel of the ear the ſonorous waves of the air flow, which, from principles of mechanics, it muſt of courſe collect together. The elaſtic air only receives ſonorous tremors or impulſions; and transfers them, either alone or principally, much after the ſame manner as we ſee water, without air, transfer any impulſe that is given to it[128]. From hence, the ſound is increaſed in air that is condenſed, and is loſt in a veſſel emptied of its air. But the medium receives theſe tremors, either from ſome body ſtriking againſt it, or from the air itſelf colliding againſt another body, or laſtly from the colliſion of two bodies againſt each other in the air. But the body which produces ſound, ought to tremble or vibrate in all, even the leaſt of its particles, ſo as to form alternate arches riſing up from the former ſtraight ſurface, and returning beyond the ſame; the curve line of the ſame exceeding that of the ſounding body. From ſuch a tremor, the contiguous air is beat into waves, whereby the parts of the air that lie outermoſt are compreſſed and fly back again ſo ſoon as their elaſticity gets over the impulſe; whence the air flies again towards the ſonorous body, where it is now more looſe and rarefied, to be there again compreſſed by impulſion; and in the ſame manner the anterior and outer portion of air, ſurrounding that which is impelled, is, by the action of the latter, compreſſed and removed farther from the trembling body, yet ſo as to return again in its proper time by the force of elaſticity, driving its contents to the tremulous body for the exciting of a new wave. Theſe oſcillations or impulſions of the air are required to ſucceed each other with a certain velocity; and, in order to render them audible, they muſt not be fewer than 30 in a ſecond of time.

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[128] That water communicates the ſonorous undulations, divers ſeem to prove; becauſe, when under water, they hear the ſound and voices of thoſe at the ſhore: and it is now beyond doubt, from the power of hearing which fiſhes poſſeſs. The indefatigable inveſtigator of nature, Lyonnet, is of opinion that inſects hear. Long ago Ariſtotle and Klein aſſerted the power of hearing poſſeſſed by fiſhes: Nollet agreed with them, but Camper has confirmed the aſſertion, viz. they have a kind of tympanum, in which there is a ſmall bone, a certain figure of a concha, receiving a nerve: they alſo have ſemicircular cartilaginous canals, through which in like manner nerves are diſtributed.

CCCCLXXIV. Acute ſounds are, in general, yielded from bodies that are hard, brittle, and violently ſhook or ſtruck; but grave ſounds are from the contrary. Thoſe ſounds in general are called *acute*, which are produced from more numerous tremors in an equal time; and thoſe *obtuſe*, which are produced from few tremors. As to any medium betwixt acute and grave ſounds, there is none but what is arbitrary. Cords, or other bodies, that yield the ſame number of vibrations in a given time, are ſaid to be *uniſon;* as thoſe which make double the number of oſcillations in that time, are ſaid to yield a tone that is an octave or eight notes higher; and other proportions betwixt the numbers of the vibrations have different names aſſigned to them. The ſhorter cords produce ſharper tones, and the reverſe, in a proportion directly as their lengths; as thoſe which are more ſtretched afford ſharper ſounds in a ſubduplicate proportion to their tenuity, or to the weights or powers by which they are ſtretched. Experiments to this purpoſe are very eaſily made with a monochord, or a ſeries of cords ſtretched with weights[129].

CCCCLXXV. The ſound, thus produced, whether acute or grave, ſtrong or weak, is carried through the air with a celerity equal to about 1038 Paris feet in a ſecond, and that with an uniform velocity, without abating in the larger diſtances. But a contrary wind, cauſing the vibrations to extend more ſlowly, retards the progreſſion of ſound about $\frac{1}{11}$ of its velocity. So likewiſe denſity and dryneſs of the air increaſe the ſound, as a rarefaction and moiſture of the air leſſen it. Hence, in ſummer time, ſounds move ſwifter; and in Guinea, it has been obſerved to paſs at the rate of 1098 Pariſian feet in one ſecond of time.

CCCCLXXVI. The ſound, thus every way extended, meets with certain particles in all adjacent bodies, even in water and mercury, to which it communicates ſimilar tremors or vibrations, not only ſuch as are in uniſon with the original tone, and which yield a ſound in a more particular manner ſenſible; but alſo it excites tremors leſs ſenſibly, even in the other parts of bodies, which vibrate in the various proportions of the ſcale. From hence it is, that every ſound which we hear, is a mixture of the original tone, produced by the trembling body, in conjunction with ſecondary tones generated from the elaſtic tremors of the ſurrounding bodies. The ſtrength of ſound is increaſed, if one audible or primary tone follows the other ſo cloſely, that their ſucceſſion cannot be diſtinguiſhed by the ear; but if they follow each other ſo ſlowly as to be diſtinguiſhable by the ear, they produce an echo; but to produce this requires an interval of ſix thirds of a ſecond of time, or the diſtance of 55 feet betwixt the reflecting or echoing body and the ear.

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[129] The doctrine of muſic undoubtedly is to be accounted among the chief proofs of human induſtry. It has recommended itſelf, not by the art by which it has been cultivated over all Europe, and particularly at Naples, but likewiſe by its effects upon animal bodies; ſo that almoſt any affections of the mind may be produced by it, and diſeaſes themſelves, particularly of the nervous kind, may be cured. Albrecht and Roger have given an abridgment of this art; but theories of this doctrine, its foundation, and conjectures upon it, have been propoſed by ſeveral celebrated perſons; ſuch as Euler, Rameau, La Grange, Burney, and ſeveral others.

CCCCLXXVII. Sounds, being elaſtic, are reflected from hard bodies in angles equal to thoſe of their incidence. But the ſame ſound, uſhered into the open air, and dilating through an immenſe ſphere, grows proportionably weaker: but if it be uſhered through a tube, in a cylindrical ſhape, the ſtrength of it is more confined together; or elſe, by being collected into the focus of a parabola or ellipſis, it becomes increaſed, as we obſerve in ſpeaking-trumpets, from which the voice goes out parallel to the focus of the parabola, without ſcattering the ſonorous rays.

CCCCLXXVIII. Therefore the ſonorous waves of the elaſtic air, being driven into the cartilaginous funnel of our ear, which is naturally inclined forward and outward in an high ſituation, are repelled and collected together, by alternate reflections from its elaſtic ſides, into the cavity of the concha, from whence it proceeds through the auditory paſſage, with a force ſo much ſtronger as the ſurſace of the outer ear is larger than the light or ſection of the auditory paſſage. Through this paſſage, however cylindrical, the ſame force is continued entire forward, and increaſed by new reſonances, excited from the percuſſion of the elaſtic cartilages and hard bones, ſo as to mix imperceptibly with the primitive ſound.

CCCCLXXIX. Moreover, the bottom or end of the ſaid auditory paſſage is terminated internally by a thin membrane, called the *membrana tympani;* which, in adults, is of a roundiſh figure, and placed with an obliquity; but ſo that from its upper appendix it projects inward like a ſhield, whilſt the part which lies above its middle projects into the cavity of the meatus like a ſhield. This membrane of the tympanum is compoſed of ſeveral plates; the firſt or outermoſt of which is white and mucous; the other is a true ſkin, continued from the membrane of the meatus, and of a vaſcular texture; the third is a dry, rattling, ſplendid, and pellucid membrane or plate, without blood-veſſels; and the innermoſt is the vaſcular perioſteum of the auditory paſſage and tympanum, with a tender cellular texture lying between. This membarne is not naturally perforated with any opening, ſo far as I have been able to diſcover, and the tranſmiſſion of ſmoke is fabulous. It is conſtantly ſo ſtretched in the ſulcus or groove of the bony ring, in which it is contained, proper to the fœtus, and after the birth coaleſcing with the reſt of the os petroſum, that there is no part of the human body to be found more tenſe or more tremulous than this. Upon the ſurface of this membrane, and more eſpecially upon its conical cavity pointing inward, the ſonorous waves ſtrike, after they have received their laſt reflections from the auditory paſſage, by which the elaſtic fabric of this membrane is forced into oſcillation.

CCCCLXXX. This membrane is ſtretched over a cavity of the os petroſum, called the *tympanum;* which is, for the moſt part, of a roundiſh figure, but not regularly ſo; being divided in its middle into two by a promontory, and in the adult is increaſed backward by the cells of the maſtoide bone, which are abſent in the fœtus. But alſo, in its upper and anterior and poſterior part, the tympanum has hollow cells, and is lined with a vaſcular membrane, receiving ſmall branches from the internal carotid, and from a branch of the artery of the dura mater, which laſt paſſes thro' a fiſſure in the aqueduct, and it has others from the external arteries of the tympanum and from the ſtylomaſtoidea. It is commonly full of a mucus, poured into it from the Euſtachian tube, and is divided by various membranes into a kind of cells, namely, by productions of the perioſteum to the little bones.

CCCCLXXXI. Within this cavity, three of the larger *bones of hearing*, together with a fourth which is leſs, are ſuſpended moveably. And firſt, the *malleus* or hammer lies with its upper round head reſting upon the concavity of the tympanum, from whence the handle of it is extended down, along the membrane of the tympanum, betwixt the plates of it: having reached as low as the middle of the membrane, it terminates by a very cloſe coheſion, with a broad extremity a little incurvated outwards. The ſame bone is, moreover, connected and ſuſtained by a peculiar ligament of its own, joining it to the longer leg of the incus; and another membrane ſerves as a ſecurity near the longer proceſs of the malleus. This bone drives outwards the membrane of the tympanum, which is ſpread over the ſhorter and conical proceſs of its handle. From the ſame place of this bone a broad, long, and flat proceſs, goes out forward into a ſulcus of the tube. It is articulated with the incus by two heads, having protuberant lines, with a ſulcus in the middle, and all of them oblique.

CCCCLXXXII. In the malleus are commonly deſcribed three muſcles: the firſt and internal of which, called *tenſor tympani*, being the largeſt, is lodged in a particular groove within the tube, with which it proceeds parallel; and, riſing from the proceſs of the multiform bone between the paſſage of the cerebral carotid and the hole of the artery of the dura mater, bending round a pully, is inſerted by its tendon reflected outward and downward into the beginning of the handle. The *ſecond* muſcle ariſes from a ſulcus in the ſame tube, but externally ſhorter than the former, and carried back almoſt in the ſame manner, but without being reflected: it adheres by a conſiderable extent to the longer proceſs; and the ſame is ſuſpected to be but little different from the red pulpy membrane. The *third* muſcle of the malleus, which ariſes from the auditory paſſage, paſſes through a notch in the broken or interrupted ring of the tympanum, and is inſerted juſt by the ſhorter proceſs into the malleus; and this, which is by ſome ſaid to relax the membrane of the tympanum, has never been ſeen with ſufficient certainty neither by myſelf, nor by the moſt eminent anatomiſts. For the reſt, by means of the tenſor of the malleus, the membrane of the tympanum is diſpoſed for the hearing of weak ſounds; as the other muſcle ſerves to moderate in too violent ſounds, by drawing the malleus from the incus; by which therefore the propagation of the ſonorous tremors is interrupted. If the membrane of the tympanum be broke, or the bones of hearing diſlocated, the perſon becomes at firſt hard of hearing, and afterwards perfectly deaf; this part being the ſeat of that ſlight hearing which is propagated through the bones of the ſkull.

CCCCLXXXIII. The malleus returns the tremors impreſſed upon the membrane of the tympanum to the incus, which is a ſhort thick little bone, articulated with the former behind by a broad ſurface, with two ſulci and a middle eminence. The ſhorter leg of this bone, whoſe little body is bifurcated, being ſuſpended by a ligament, is held firm into a ſulcus proper to the bone. Another longer one deſcends parallel to the malleus; and, by a ſomewhat crooked extremity, is adapted to the fourth orbicular bone which it receives, convex on one ſide, flatter on the other, and reſting upon the ſtapes, to which its protuberances are imparted.

CCCCLXXXIV. The *ſtapes*, aptly enough ſo called from its figure, lies inclined, but more backward than forward, with a hollow head that receives the incus, from whence proceed two little crooked legs, the poſterior one of which is largeſt: but below, its oval baſis is occupied by an aperture of a correſponding figure, commonly called the *feneſtra ovalis*. Here the legs, which are ſulcated inwardly, are conjoined by a tenſe membrane affixed to the hollow baſis. This bone of the ſtapes is covered by its own muſcle, which being included in a bony papilla or caſe, ſends out a ſmall tendon, which is inſerted under the incus into the head of the ſtapes. Hence it ſeems to draw the ſtapes, that it may lie higher up, under the back part of the feneſtra ovalis, and paſs out of it before. Thus the nervous pulp of the veſtibulum is preſſed by the baſis of the ſtapes, and by the air of the tympanum. The whole courſe or ſeat of the ſtapes is ſeparated from the reſt of the tympanum, by a membrane proper to itſelf,

CCCCLXXXV. A ſmall roundiſh oval-ſhaped bone, here and there greatly excavated, is here fixed to the longer leg of the incus, and from thence goes to the ſmall head of the ſtapes.

CCCCLXXXVI. There are various channels which paſs out from the cavity of the tympanum. Above the two larger bones behind the poſterior leg of the incus, is a ſmall cell, a kind of appendix to the tympanum, of the figure of a gnomon. Behind that the ſmall cells begin in the os petroſum, above the mamillary proceſs. Below theſe, that proceſs is excavated in an adult by various ſmall caverns.

CCCCLXXXVII. From thence the proper canal, going out forwards from the anterior extremity of the tympanum, emerges from the bones lying between the os multiforme and the oſſa temporum; and is joined into a correſponding elliptical and diverging cone, partly membranous, and in part made up of cartilages of a variable ſtructure; it opens by a very ample elliptical aperture, turning inward and forward behind the nares, into the cavity of the fauces: it is lined with a porous membrane, full of cryptæ and mucous cells, continued from and like to the membrane of the nares. This is the *tube* which, by the action of the circumjacent muſcles, may be compreſſed and cloſed, and probably a little relaxed and opened again, by the circumflex muſcle of the moveable palate. By this canal the inſpired air enters into the tympanum to be changed or renewed, and the ſurrounding mucus of the little bones and other parts are this way depoſited: nor is it at all improbable, that the air enters by this tube, to ſupport the tympanum when it is preſſed inward by the more violent ſounds; for ſounds themſelves, received into the mouth, are this way conveyed to the organ of hearing.

In inſpiration, the air preſſes the membrane of the tympanum outward: and from thence proceeds that claſhing or whiſpering noiſe, by which the hearing is obſcured, when the mouth is held wide open in yawning; for then the air entering more abundantly through the cavity of the tube, to the tympanum, reſiſts the tremors of the external air.

CCCCLXXXVIII. Two other paſſages lead from the tympanum to the *labyrinth*, or innermoſt chamber of the ear[130]. And, again, the feneſtra ovalis (CCCCLXXXIV.) not covered by any membrane, leads into the *veſtibulum;* which is a round cavity, formed in a very hard part of the os petroſum, that lies near the inner part of the tympanum. In that cavity are three receſſes; of which the upper one is elliptical, the lower one circular, and the third like a furrow. There is a nervous pulp in the veſtibulum diſtinguiſhed from the parietal bone by the vapour ſurrounding it[131]. Into this open the five mouths of the three ſemicircular canals, the foramen ovale, and the paſſages of the nerves and arteries.

CCCCLXXXIX. In the fœtus, theſe are formed of a diſtinct hard ſhell, which being ſurrounded with a ſpungy bone, are lodged in a cavity of the os petroſum; which, in adults, is extremely hard, extended into ſegments ſomething larger than ſemicircles, which have an

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[130] There is almoſt no part of the human body ſooner acquires its perfect magnitude than the labyrinth of the internal ear: for in a fœtus of five months, it is almoſt of the ſame ſize as in an adult.

[131] All the internal cavity of the labyrinth is filled, not with vapours, but with true water. In 1771, I had two caſes of perſons who died through cold, in whom an icy ſtria could be perceived penetrating through the feneſtra ovalis, the ſtapes being driven out from the veſtibulum into the cavity of the tympanum. No perſon before Cotun, although Vieuſſens, Salzman, Valſalva, Morgagni, &c. had ſome knowledge of the ſubject, was really and fully acquainted with this water, which Caldan and Meckel have more fully confirmed. The whole cavity of the labyrinth, particularly of the veſtibulum, is filled with it: if you inject quickſilver, it is expelled; or by cold, it is converted into ice, exactly repreſenting the figure of the cavity: This is ſeen in ſeveral animals. It is ſecreted from the arteries, and thrown out by two ſmall canals, through which at leaſt mercury goes from the cavity of the labyrinth.

ample opening betwixt them. The larger poſterior and lower of theſe circles is perpendicular; alſo the middle and upper one is placed towards the perpendicular; but the outermoſt and leaſt is horizontal. The inner mouth or aperture of the uppermoſt of theſe meets with the upper opening of the poſterior ring, and both join into one.

CCCCXC. But the cochlea is a part ſtill more wonderful, ſeated in an inclined poſture within the anterior portion of the os petroſum. Into one part of this cavity opens the veſtibulum; and into the other the *feneſtra rotunda* of the tympanum [132], which is concealed behind a protuberance in the bottom of the tympanum. The cochlea itſelf is made up of a nucleus of bone, of a conical figure, with its apex inclined inward; divided by a middle ſulcus, both through its baſis, and through its whole length; and perforated with innumerable ſmall foramina into the tubes, which are called *ſcalæ*, terminating in the middle of the ſecond ſpiral. About this nucleus are wrapt two turns and a half of a canal; which in the fœtus is made up of a diſtinct ſhell-like ſubſtance, peculiar to itſelf; and, in the adult, is united into one, with the adjacent bone: and this winding canal diminiſhes gradually in a conical figure, from the two forementioned openings towards the tip of the nucleus. It is bilocular, or made up of two apartments, divided by a partition called *lamella ſpiralis*. This, at its larger end, is bony, and extended out of the nucleus, at right angles, into a cavity; is ſtriated, and every way wrapt up by the internal perioſteum as in a capſule. Another external part hereto belonging, is a membrane, which likewiſe divides the canal: thus there are formed two diſtinct ſemicanals, called *ſcalæ*. The interior and poſterior of theſe canals begins from the feneſtra rotunda, where it is ſhut by a membrane, and is called the *ſcala tympani*; the other begins before, from the veſtibulum, from which it has its name. In the tip of the cochlea is formed a third cavity ſhaped like a funnel. Into this the ſpiral lamina terminates by a membranaceous extremity, but ſo that the funnel communicates with them by a ſmall hole on each ſide; but, in many bodies, it alſo communicates with the cavity of the bucket that is filled with the nerve.

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[132] It is now very clear to all from the obſervations and figure of Scarpa, although it was not known before.

CCCCXCI. The blood-veſſels of the outer ear come from the temporal or proper auricular branches; thoſe to the membrane of the tympanum are either from the temporal, from the ſtylo-maſtoideal, or from both; thoſe of the meatus auditorius come from the former; thoſe to the tympanum were deſcribed CCCCLXXX.; and the veſſels belonging to the veſtibulum, cochlea, and ſemicircular canals, are from the vertebrals and ſtylo-maſtoideals. The induſtry of late anatomiſts has diſcovered veſſels of a particular kind, proper for carrying back liquids from the veſtibulum into the tranſverſe ſinus, from the cochlea into the cavity of the ſkull.

CCCCXCII. It now remains that we deſcribe the nerves deſtined to the ſenſe of hearing, of which the principal is that called the *ſeventh* (CCCLVII.) This nerve enters into the internal auditory ſinus of the os petroſum, in the blind end of which it divides. The ſmaller part of the nerve is ſent upward, through the opening of a canal in the ſinus; whence paſſing tranſverſely, it is afterwards bent behind the tympanum. In this part deſcending, it gives off a branch through a peculiar channel to the tympanum, which aſcends betwixt the malleus and incus, and goes out of the tympanum, through a fiſſure behind the articulation of the lower jaw, afterwards inſerting itſelf into the nerve of the tongue (CCCCLVII.); the reaſon of which ſecret communication is obſcure, but ſerves to explain the conſent of the teeth ſet on edge by ſharp ſounds, a removal of their pain by burning the ear, &c. The reſt of the nerve, eſcaping by the ſides of the ſtyloide proceſs, is diſtributed through the external ear, the parotid gland, a large part of the the face, and upper part of the neck, both cutaneous and muſcular; and in the face forms numberleſs inoſculations, both betwixt its own branches, as well as with thoſe of the firſt, ſecond, third, and fifth pair; and it likewiſe communicates with the eighth pair, and the third cervical pair. But to the immediate organ of hearing it ſends either no branches, or at leaſt very ſmall ones. The outer ear again receives other nerves in its fore part from the third branch of the fifth pair, and in its back part to the ſecond and third of the cervicals.

CCCCXCIII. But the *ſoft portion* of the auditory nerves ariſes larger, but more obſcure, from the fourth ventricle of the brain itſelf (CCCLVII.) and enters by very minute threads through exceeding ſmall holes of the inner auditory ſinus, which go in part to the veſtibulum, and in part to the ſurface of the cochlea. The branches in the veſtibulum form a pulp-like tender membrane[133], which is every way extended through the ſemicircular canals. The other part, entering the furrow of the cochlea, has an obſcure termination.

CCCCXCIV. With reſpect to the nerve which is diſtributed through the veſtibulum and ſemicircular canals, there is no doubt but it is ſtruck by the tremors of the external air, propagated to the ſtapes; from whence the tremors immediately paſs through the oval feneſtra, to preſs upon the naked pulp of the nerve. That part of the nerve which enters the cochlea is altogether obſcure in its termination. It is probable, that ſmall branches from thence paſs through the little foramina (CCCCXC.) to the perioſteum of the cochlea, and to the membranous part of the ſpiral partition. Do the tranſverſe nervous filaments paſs out from the nucleus of the cochlea, all the way ſucceſſively ſhorter through the ſpiral plates? Is it the organ of hearing? Theſe are queſtions, which we are yet hardly able to reſolve from anatomy; though this ſeems repugnant to the courſe which we obſerve nature takes in brute animals, in birds, and in fiſhes, who all hear very exquiſitely without any cochlea. However this may be in the human body, it is there probable, that the ſpiral plate, ſpread full of nerves, is agitated with tremors from the oſcillations of the membrane of the tympanum, by which the air in the cavity of the tympanum is agitated, ſo as to preſs the membrane of the round feneſtra, which again agitates the air contained in the cochlea.

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[133] The veſtibulum is divided by a certain proper membranaceous ſeptum into two parts, over which a great portion of the ſeventh pair is diſtributed: the reſt of it is diſtributed almoſt in the ſame manner over the cochlea as the optic ends in the retina.

CCCCXCV. The preceding conjecture is indeed elegant; ſince the ſpiral plates make up a triangle, ending in a ſhort point towards the tip, by which it may be conceived to contain an infinite number of nervous cords, continually ſhortening in their length; and by that means adapted to an harmonical uniſon or conſonance (CCCCLXXIV.) according to the variety of acute and grave ſounds, ſo as to tremble together at the ſame time with moſt of them; namely, the longeſt cords in the baſis of the cochlea with grave ſounds; and the ſhorteſt cords nearer the tip or apex, with the ſharper ſounds. Whether are ſounds perceived in the middle ſemicircular canals, when theſe alone are found in all claſſes of animals? Are they detained in theſe canals, in the cochlea, and by the membrane ſuſpended through the veſtibulum? This ſeems probably the caſe.

CCCCXCVI. From what has been ſaid, it appears, that the elaſtic waves or tremors of the air arrive thro' the outer ear and auditory paſſage, to the membrane of the tympanum; which being injured, and not repaired, the hearing is totally deſtroyed. This ſeems to be ſtretched, for hearing weak ſounds, by the muſcles of the malleus. From this membrane the ſound is conveyed through the ſmall bones to the veſtibulum; for theſe bones being deſtroyed, the hearing is again aboliſhed. The bony ſides of the veſtibulum, by their tremulation, agitate the ſmall quantity of aqueous fluid ſurrounding the nervous pulp. It ſeems to be ſtruck by the nervous pulp ſuſpended in the veſtibulum, and that tremor to be continued through the continuous pulp of the cochlea and ſemicircular canals. Of more than this we are not certain: but, by undoubted experiments, tremors, and even elaſtic ſounds, communicate themſelves by the internal Euſtachian tube, and through all the bones of the ſkull, ſo as to impreſs their force upon the auditory nerve.

CCCCXCVII. The diſtinction of ſounds, doubtleſs, proceeds from the celerity of the tremors excited in the hearing nerve, according as they ſucceed each other more ſwiftly or ſlowly, in a ſhort time; in order to which it is not neceſſary the mind ſhould number them; it is ſufficient that ſhe perceive their numbers to be different, and that this difference excites a variation in her thoughts and ideas thence ariſing. Whether the harmony or agreeableneſs of ſounds ariſes from the number of parts ſounding together in uniſon? and whether the mind, ignorant of herſelf, numbers the degrees of conſonance, ſo as to pleaſe herſelf in a majority of them? theſe are queſtions denied by the moſt expert muſicians, who make it appear, that there is an agreeableneſs, and that very conſiderable, in ſounds approaching the leaſt to a conſonance, and which lies in a proportion very difficult to determine. Why do ſounds often become too ſharp for the ear? Our auditory nerves ſeem to be ſtrained upon the ſpiral plates, in ſuch degrees as to be in danger of breaking, after the manner drinking-glaſſes may be broke by ſharp ſounds, and as the hearing is ſometimes almoſt loſt for a while by the violently ſhrill whiſtlings of the inhabitants of the Canary iſlands.

END OF VOLUME FIRST.